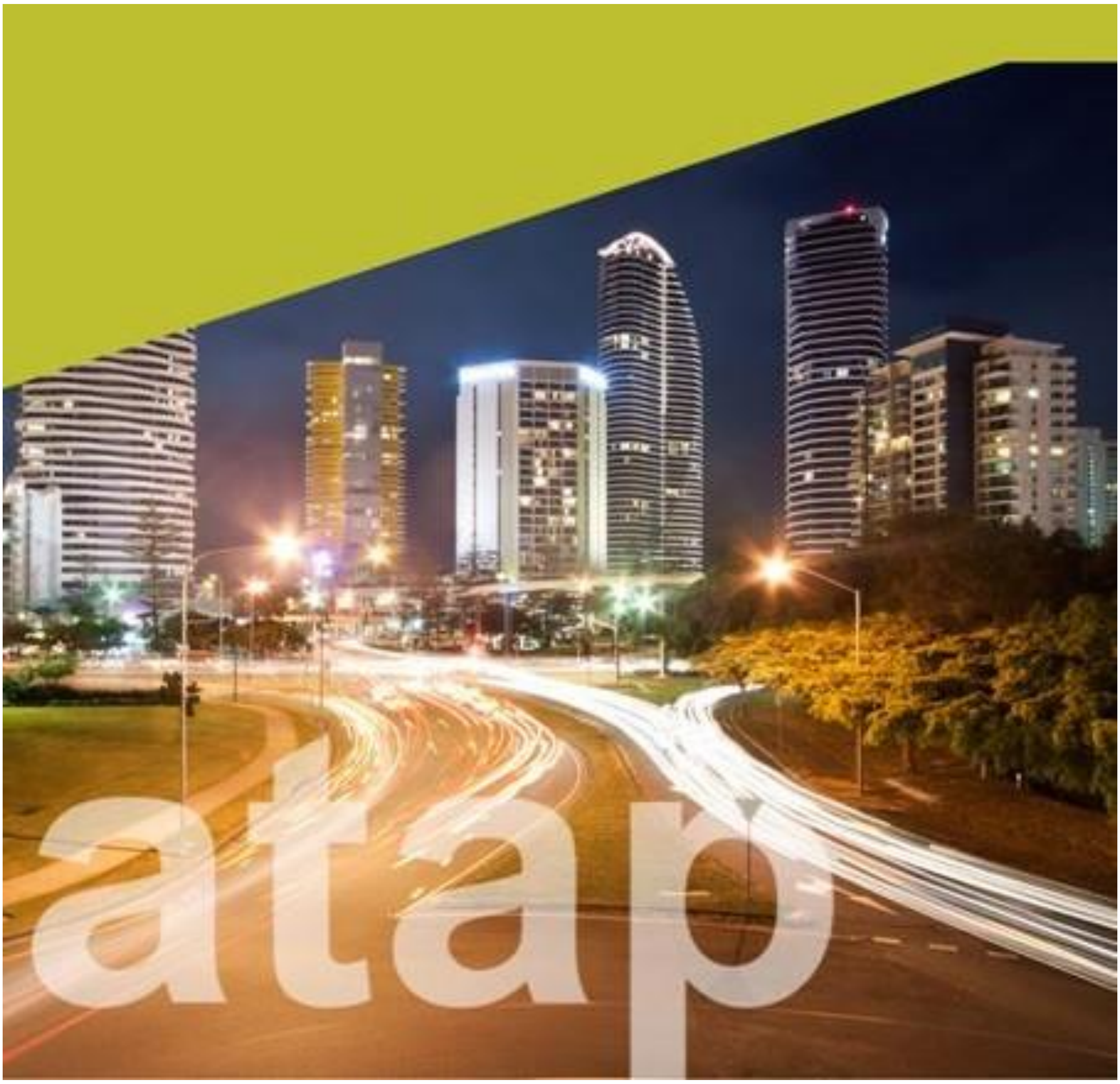
INFRASTRUCTURE AND TRANSPORT MINISTERS

Australian Transport Assessment and Planning Guidelines

M1 Public Transport: Parameter Values Technical Report

August 2021



ISBN 978-1-925701-63-0 INFRA-3689

August 2021 (previous version September 2018)

This report was written by Neil Douglas for the ATAP Guidelines (editor: Peter Tisato). The following people are also acknowledged:

Reviewers of drafts

Members of the ATAP Steering Committee for the 2021 update: Mark Harvey, Andreas Bleich, Belinda Sachse and Paula Stagg (Australian Government), Atiqur Rahman, Paul Stanley and David Tucker (Infrastructure Australia), Alban Pinz (QLD), Robert Smith and Matthew Jones (NSW), Justinieta Balberona (ACT), Ed McGeehan (VIC), Arun Kendall (TAS), Scott Cooper and Aaron Bell (SA), Des Lock (WA), Brett Clifford (NT), Sandy Fong (NZ), Richard Delplace (Austroads), Peter Tisato (Technical Coordinator).

Contact us

This publication was prepared by the Australian Transport Assessment and Planning (ATAP) Steering Committee and approved by the Transport and Infrastructure Senior Officials' Committee. The Committees cannot accept responsibility for any consequences arising from the use of this information. Readers should rely on their own skill and judgment when applying any information or analysis to particular issues or circumstances.

ATAP Steering Committee Secretariat

Australian Transport Assessment and Planning Guidelines

Department of Infrastructure, Transport, Regional Development and Communications

GPO Box 594

Canberra ACT 2601

Australia

Email: atap@infrastructure.gov.au

Website: atap.gov.au

Contents

Figures

Tables

Summary

S1 Value of public transport in-vehicle time

The value of in-vehicle time (IVT) is an important parameter in forecasting demand and project appraisal, enabling travel times to be converted into dollars so as to compare travel time savings with project costs.[1] The value of IVT also provides a base against which other travel time components such as access walk time can be valued by applying 'IVT multipliers' (see Section S2 below). In this context, the value of IVT presented here, unless otherwise stated, is for seated onboard time on a bus, train or ferry in the average quality vehicle as perceived by users.

It is important to note that value of IVT plays two distinct 'roles' in transport assessment: a) demand forecasting, and b) in estimation of benefits of initiatives: [2]

- For *demand forecasting*, behavioural values representing willingness-to-pay (WTP) values should be used. WTP values tend to vary between modes and travellers with different income levels. The values presented in this report are behavioural values.
- For the *appraisal of initiatives*, common practice in Australia and around the world (UK Government, 2017, NZ Transport Agency 2017, DAE, 2016) has been to use 'equity' values of time, where the same IVT value is used across all modes and individuals with the aim of according equitable treatment to people with different WTP values arising from differences in income levels.[3] The values of time provided in Part PV2 for car travel should be used as equity values and applied for appraisals of initiatives across all modes.[4] On completion of the current ATAP WTP investigation, further consideration will be given to a suitable equity value based on a weighted average of car and public transport behavioural values will be considered.

The estimates were derived from a regression analysis of 31 Australian and NZ studies, mainly Stated Preference surveys undertaken between 1990 and 2014. Most of the studies (27) were undertaken in Australia (of which 21 were NSW studies with 4 New Zealand studies. Altogether the studies provided 132 observations. In most instances, public transport users were surveyed but a few studies did survey car users about their preferences for travelling by public transport. Analysis did not discern any significant differences in the valuations of car and public transport users. Figure 1 plots the observations and shows how the value of time has trended upwards over the 24-year period.

There are a range of approaches to update the value of time. Section 2.2 outlines a selection. An important deciding factor on what index to use is whether the updating is to a new 'base' year or

[1] Other components, such as access time, are also converted into dollars after they have been expressed in equivalent in-vehicle time minutes (see Section S.2 below).

[2] In four studies reviewed (35, 36, 37 and 38), the valuations were standardised for income allowing the estimated parameters to be adjusted for income.

[3] Average income for travellers varies with mode. Often stated is that public transport users have on average lower incomes than car users, although this may not be the case for rail and car commuters — see for example: https://www.bitre.gov.au/sites/default/files/Income_and_public_transport_IS102_Web_Accessible.pdf . This leads to behavioural values of IVT being lower for public transport than for cars. As a result, using behavioural values of time in an appraisal would create a bias against lower income people using public transport relative to higher income people using cars. To avoid this, the same common value of IVT or 'equity value' is used across modes and individuals for transport appraisal purposes. Douglas and Legaspi (2018) have estimated a weighted average value of time for NSW.

[4] There is a need for care in applying an equity value of time when travel time multipliers have been used in an urban travel demand model. For instance bus or car travel time may be multiplied by a factor of say 1.2 or 1.5 in order to express travel time in equivalent rail time minutes. If the value of time reflects car users, then applying it to a travel time expressed in rail time minutes will over monetise the time saving.

whether it is to project the value of time through an evaluation period. To update the value to a base year, the indices used should be in current prices (nominal or prices of the day) whereas for projecting the value through an evaluation period, the indices should be in real (constant or inflation adjusted prices).

Analysis of the Australian and New Zealand studies found that the value of time increased well above consumer price inflation over the 24-year period and so an ‘elasticity’ above one was needed for inflation to track value of time growth. Nominal wage rate and National GDP per capita were closer (and thus needed an elasticity closer to 1). Wage rates have been used to update values of time in some Australia jurisdictions. The UK has used GDP per capita with GDP expressed in current prices (i.e. not the GDP measure commonly reported by the media which is ‘deflated’ for price inflation).

If the value of time is projected to rise in real terms through the evaluation period (rather than remain constant) then either real wages or real GDP per capita could be used.[5]

Figure 1: Value of time over time $/hr

Values in local currency in current prices and include GST (mid 2014 dollars)

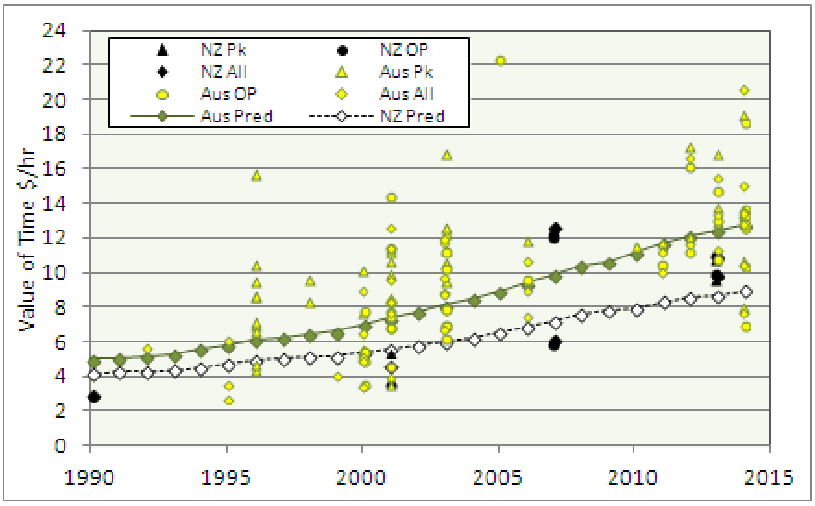


Table 1 provides values of IVT for public transport users in 2019 prices. The values are expressed in 2019 market prices and since they were estimated in studies that compared travel time with fare they include GST levied at 10% in Australia and 15% in NZ on PT fares.[6] The overall value of IVT in national currencies is:

- $14.20/hr for Australia
- $NZ 9.90/hr for NZ
- The values for peak travel are a fifth higher than for off-peak travel. For Australia, the peak VOT was 15.40/hr compared to $13.00/hr in the off-peak
- VOT varied by mode. For Australia, the VOT was $16.00/hr for rail, $14.50/hr for tram/LRT, $12.30/hr for bus and $20.80/hr for ferry.

[5] If values of time are projected to rise in real terms through the evaluation period then for consistency capital and operating costs should also be increased to take account of the proportion of costs that are labour related.

[6] Strictly, values should be discounted at the average rate of indirect taxation in the economy which includes other taxes and duties besides GST.

Table 1: Values of public transport in-vehicle time by mode

Values in local currency in 2019 prices and include GST

Time	Australia (Aus $)					New Zealand (NZ$)				
Period	Rail	Tram	Bus	Ferry	All	Rail	Tram	Bus	Ferry^	All
Peak	17.30	15.80	13.30	22.50	15.40	12.90	na	10.00	16.80	10.80
Off-Peak	14.50	13.20	11.20	18.90	13.00	10.80	na	8.30	14.10	9.00
Overall	16.00	14.50	12.30	20.80	14.20	11.90	na	9.20	15.40	9.90

^ estimate based on Australian surveys since no ferry services were surveyed in NZ

Values include Goods and Service Taxation (GST) levied at 10% for Australia and 15% for NZ.

Table 2 presents guideline factors to calculate the value of IVT by trip purpose for public transport travel. The values have been expressed as a ratio of the average value of IVT. For commuting to/from work, the value of IVT is 115% of the average which for Australia would be $16.30 ($14.20 x 1.15).

Trips to/from school, college and university valued IVT at 76% of the average. Company business trips had the highest value of IVT at 163% of the average but accounted for only 2% of urban public transport trips.

Table 2: Journey purpose values of time and trip shares

Ratio of trip purpose value of IVT (VOT) to average VOT

Statistic	To/From Work	Educ-ation	Personal Business	Company Business	Shop-ping	Visiting Friends/ Relatives	Entertain ment/ Holiday	Other	All
VOT/Av Ratio	115%	74%	95%	163%	93%	83%	89%	88%	100%
Trip Share	47%	17%	9%	2%	7%	8%	8%	2%	100%

Based on studies 22, 37, 38, 39 & 40.

Between 2012 and 2015, Transport for NSW (TfNSW) undertook a comprehensive survey of the value of travel time (VOT) for car as well as public transport users. The principal aim was to test the 40% wage rate assumption that has been the basis for valuing private car travel time in NSW since the late 1990s.

The response to the large sample supported a 40% wage rate assumption for private travel time by car (commuters 44% and other trips 37%) and for commuting trips by public transport which was exactly 40%. However a lower valuation of around a quarter the wage rate was estimated for non-commuting private travel trips by public transport reflecting lower incomes and fare concession use (which conditioned users to time savings at half or a significantly discounted price). In terms of application and updating, the TfNSW results can easily be projected on the basis of average hourly earnings (AHE) keeping the wage rate share constant.

In terms of equity, the TfNSW study investigated the effect of income on VOT and developed a set of income standardised values. Standardisation has the advantage of taking into account income but allowing for differences in mode 'quality'.

Table 3: Estimated Values of Time by Trip Purpose by TfNSW 2015 Study

Trip Purpose	Value of Time $/hr			Percentage of Wage Rate^			Av. Income $000 p.a.		
	Car	PT	ALL	Car	PT	ALL	Car	PT	ALL
Commuting	16.58	14.98	16.13	44%	40%	43%	68	64	67
Other Trips#	14.14	8.94	13.57	37%	24%	36%	52	38	50
All	14.63	11.32	14.13	39%	30%	37%	55	48	54

^ Calculated as percentage of $37.85/hr. Car shares 72% commuting, 89% other and 85% overall.

Excludes trips travelling on company business

It should be noted that the values of time shown inTable 3 are behavioural values of time rather than resource values (see discussion in Part M1 section 5.1).

A subsidiary aim of the TfNSW study was to test whether the value of time increases with trip length as some analysts have argued. It was found that although the sensitivity of respondents to the time and cost differences did decline with trip length they both declined at a similar rate which left VOT (which is ratio of the two sensitivities) largely unaffected. This result supports the simplifying assumption of keeping the value of time constant across the study area in demand forecasting models and in evaluations.

S2 Travel time multipliers for 'travel convenience' factors

A set of guideline travel time (IVT) multipliers were derived from a review of 40 Australian and New Zealand studies that covered: walk access/egress, service interval (service frequency), travel time displacement (not travelling at the most desirable time), interchange (transfer penalties and connection time), onboard crowding and reliability.

To calculate a generalised time measure, the weighted components can be added as shown in equation S2. All the components are included in the equation although in practical applications some components may be omitted if they do not change.

$$GT = m_{ae}AE + m_{si}SI + \left(m_{tp}TP + m_{tct}TW\right) + IVT + m_{cwd}IVTCWD + m_{rel}REL + \frac{60}{VOT}FARE \quad \text{(S2)}$$

where:

GT = generalised time in minutes

AE = access/egress 'out of vehicle' walk time

SI = service interval (mins between departures)

TP = transfer penalty (number by type)

TW = transfer connection walk and wait time

IVT = in-vehicle time (mins)

$IVTCWD$ = in-vehicle time in crowded conditions (multiplier should be 'net' i.e. minus 1)

REL = reliability measure

$FARE$ = fare in dollars

VOT = value of in-vehicle time ($/hr) in uncrowded seated conditions

m_x = respective multiplier to convert into equivalent IVT minutes.

The generalised time measure can be converted into generalised cost by multiplying by the value of time given in Table 1 or Table 2.[7] Table 4 presents the guideline travel time multipliers which are expressed relative to seated time in uncrowded conditions on an average quality vehicle.

Table 4 also includes a column showing multiplier values estimated by an OECD study by Wardman (2014). It is seen that the OECD and Australian study values are reasonably close.

Table 4: Summary of travel time multipliers

<table>
<tr><th>Attribute</th><th colspan="6">Australian/NZ Review</th><th>OECD Review</th><th>Notes</th></tr>
<tr><td>Service Interval</td><td colspan="6">0.70</td><td>0.5 - 0.8</td><td rowspan="3">The SI/IVT value of 0.7 allowed for a upward trend in valuation over the review period and compares with an average of 0.64 based on 115 obs. A curvilinear function was estimated which declined from 0.93 for a 5 min service to 0.65 for a 20 min service to 0.37 for an hourly service.</td></tr>
<tr><td>SI (mins/depts)</td><td>5</td><td>10</td><td>20</td><td>30</td><td>40</td><td>60</td><td rowspan="2">na</td></tr>
<tr><td>SI/IVT Valuation</td><td>0.93</td><td>0.83</td><td>0.65</td><td>0.52</td><td>0.44</td><td>0.37</td></tr>
<tr><td rowspan="2">Travel Time Displacement</td><td colspan="2">Early</td><td colspan="2">Late</td><td colspan="2">Average</td><td>Average</td><td rowspan="2">The cost of not being able to travel at the desired time. There were only two Sydney studies giving early displacement at 0.5, late displacement at 0.75 and Av Disp at 0.6. The recommended values are lower based on analysis of the SI function and the OECD review.</td></tr>
<tr><td colspan="2">0.33</td><td colspan="2">0.50</td><td colspan="2">0.42</td><td>0.4 - 0.6</td></tr>
<tr><td>Wait Time</td><td colspan="6">1.40</td><td>1.75 - 2</td><td>Valuation based on decomposition of SI valuation.</td></tr>
<tr><td rowspan="2">Net Transfer Penalty (mins of IVT)</td><td colspan="3">Same Mode Transfer</td><td colspan="3">Different Mode Transfer</td><td>Penalty</td><td rowspan="2">21 studies provided 75 observations from which the average net transfer penalty (excluding time spent at the transfer) averaged 6 minutes for a same mode transfer e.g. bus to bus or train to train. For transfers involving a change of mode e.g. bus to train, the net transfer penalty averaged 10 minutes. For rail, two Sydney studies estimated a cross-platform penalty to be 2 minutes less than a change in platform.</td></tr>
<tr><td colspan="3">6</td><td colspan="3">10</td><td rowspan="2">5 - 15 (Gross included transfer time)</td></tr>
<tr><td>Transfer Connection Time</td><td colspan="6">1.50</td><td>Time at the transfer (largely waiting time) was valued at 1.5 x IVT based on 25 observations. Valuation likely to vary with walk/wait & conditions (seating/shelter & crowding).</td></tr>
<tr><td rowspan="2">Crowding Multipliers</td><td colspan="2">Crowded Seat</td><td colspan="2">Standing</td><td colspan="2">Crush Standing</td><td>Standing</td><td rowspan="2">14 studies (30 obs) estimated crowding multipliers. Crowded seating time was valued a fifth higher than uncrowded seating. Standing multiplied the time cost by 1.65 with crush standing more than doubling the cost (2.11).</td></tr>
<tr><td colspan="2">1.20</td><td colspan="2">1.65</td><td colspan="2">2.10</td><td>1.5 - 2</td></tr>
<tr><td rowspan="2">Reliability (Average Mean Lateness)</td><td colspan="2">At Stop Departure</td><td colspan="2">On-vehicle Arrival</td><td colspan="2">Average</td><td>Lateness</td><td rowspan="2">10 studies (15 obs) measured reliability as Average Mean Lateness (AML) calculated as the proportion of services late multiplied by the number of minutes late. Departure AML at stops was valued higher at 5.9xIVT than vehicle or arrival AML at 2.8. The average AML valuation was 4.1.</td></tr>
<tr><td colspan="2">5.9</td><td colspan="2">2.8</td><td colspan="2">4.1</td><td>3 - 5</td></tr>
<tr><td>Access/Egress: Walk</td><td colspan="6">1.50</td><td>1.75 - 2</td><td>21 studies (19 SP, 2 RP) gave av. multiplier of 1.32 however 2 studies of actual behaviour (Sydney Travel Model calibration) gave higher value of 1.5 and this value is recommended. Valuation will increase where greater effort involved (e.g. 4 for up stairs) or in high crowding (2.3).</td></tr>
</table>

[7] As the generalised time measure is in minutes and the value of time is an hourly figure, to convert to dollars the GT measure should be divided by 60 and then multiplied by the value of time ($/hr).

S3 Value of vehicle quality

The values for vehicle quality relate to the provision (or not) of onboard facilities such as passenger information displays and air conditioning and to the level of 'operational' quality such as the cleanliness and the friendliness and helpfulness of the bus driver.

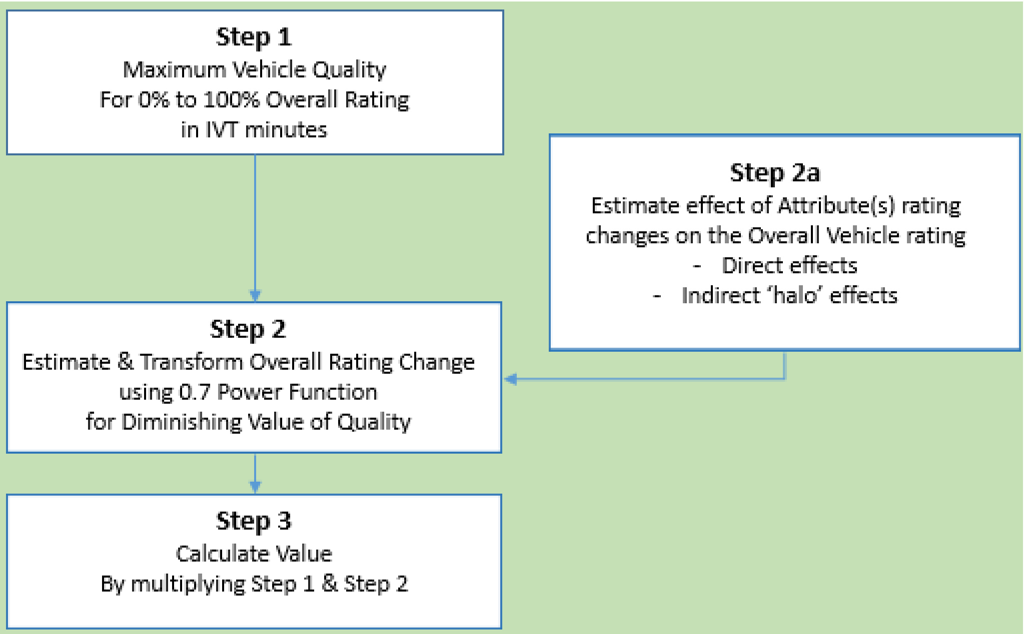
The values have been estimated based on three large-scale market research surveys undertaken in NZ (Auckland, Christchurch and Wellington), NSW and Victoria in 2012-14. These three studies used the same hybrid approach involving Stated Preference and rating questionnaires. For rail, the 2012-14 rating surveys were supplemented by similar surveys conducted a decade earlier in Wellington and in NSW.

The surveys used passenger ratings that assess quality on a percentage scale from 'very poor' 0% to 'very good' 100%. Valuing the change in rating involves a three step approach as shown in Figure 2.

Step 1 determine the maximum 'Willingness to Pay' for quality (for a 100% change in rating) expressed in in-vehicle time minutes. Step 2 transforms the rating change to allow for 'willingness to pay' to decline as quality improves. Step 3 multiplies the maximum value of quality by the transformed change.

To value improvements to individual attributes (or packages of attributes) the three step approach is extended via a 'step 2a' in which the change in attribute rating is multiplied by an importance factor. The step also allows for changes in the rating of one individual attribute to affect the ratings of other attributes via a 'halo effect' and thereby indirectly increase the overall rating.

Figure 2: Three Step Valuation Approach



The maximum value of vehicle quality (MVQ) was estimated through Stated Preference surveys and was found to increase with trip length. For public transport, MVQ increased at half the rate of the onboard trip time from a base of 4 minutes. With the average trip length the maximum value of vehicle quality (MVQ) was 17.5 minutes. There were differences in MVQ by mode as Table 5 shows.

Table 5: Maximum Vehicle Quality

Value of a 100% rating difference (Very Poor to Very Good) in Equivalent IVT minutes

Mode	Max Veh Quality (MVQ) mins		MVQ/Trip	Av Trip	Evidence
	Constant	Per Minute	IVT mins	IVT mins	
Rail	4.4	0.55	23.7	35	NZ, NSW, VIC
Tram/LRT	3.2	0.41	11.4	20	NSW, VIC
Bus	3.2	0.40	13.2	25	NZ, NSW, VIC
Ferry	1.3	0.43	11.6	24	NSW
Public Transport	4	0.5	17.5	27	ALL

It is highly unlikely that the maximum value of quality (100%) will apply since not everyone would rate a vehicle at 0% (very poor) before an improvement and 100% (very good) after it. Thus, the change in rating will be less than MVQ. A 40% to 80% change is considered a reasonable range for a major improvement in vehicle quality.

It would be incorrect to multiply 40% with MVQ to value the change because the WTP for quality was found, through the Stated Preference surveys, to decline with quality. The decline is approximated by a power function with the rating raised to the power of 0.7 which reduces the 40-80% change from 40% to 33%.

There will be instances where changes to individual vehicle attributes or combinations of attributes need to be evaluated rather than changes to overall vehicle quality such as a change to vehicle cleanliness or to driver/staff friendliness. To evaluate a change in one attribute or a combination of attributes, an additional step is needed. This step is referred to as step 2A.

Step 2A takes account the relative importance of different vehicle attributes. Importance measures the extent to which the overall vehicle rating is likely to change in response to a change in attribute rating. Importance was established by regression analysis of the NZ, NSW and Victoria ratings data. Regression explained the variation in the overall vehicle rating in terms of the individual attribute ratings.

Five attributes explained most of the variation in the overall vehicle rating: outside vehicle appearance, ease of getting on and off, seat availability and comfort, smoothness and quietness, and cleanliness and graffiti. Each attribute typically explained 10% to 15% of overall importance. The main report tabulates the importance of 16 attributes.

Step 2A multiplies the change in attribute rating with its direct importance to determine the change in overall rating which is then added to the base overall rating to get the new overall rating. The base and new ratings are then transformed to calculate the WTP.

Analysis of Sydney ratings found vehicle attribute ratings to be positively correlated. As an example, the strongest correlation was between ‘space for personal belongings’ and ‘seat availability and comfort’ (r=0.7). Improving one attribute was therefore likely to increase the rating of other attributes as well as its own rating and, by so doing, increase the overall vehicle rating more than the ‘direct’ effect. The indirect effect is referred to as the ‘halo effect’ and is added to the direct effect to get the total effect.

In doing an evaluation to assess the passenger benefits of renewing or refurbishing a vehicle, a rating survey should be undertaken to assess at least the passenger rating of the base quality. It will probably be difficult to survey the new or refurbished vehicle of course. Over a period of 2 decades, RailCorp NSW undertook passenger rating surveys as part of developing its library of demand parameters for economic and financial evaluation. These surveys plus the 2012-2014 surveys have been summarized in the main report to provide benchmark ratings.

Altogether, ratings for 110 vehicle types (92 bus, 19 train, 6 tram, 1 LRT and 8 ferry) from 26,094 questionnaires completed in NSW (Sydney, Newcastle and Wollongong, NZ (Auckland, Christchurch and Wellington) and Victoria (Melbourne) were analysed. Table 6 presents a summary.

Table 6: Average, Maximum and Minimum Vehicle Ratings by vehicle type

NZ, NSW and Victoria 2012-2014 Surveys

Attribute	Average Rating					Bus		Tram/LRT		Rail		Ferry		All	
	Bus	T/L	Rail	Ferry	All	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Outside Appearance	73%	74%	67%	75%	72%	88%	55%	81%	62%	84%	46%	85%	69%	88%	46%
Ease of On & Off	77%	77%	75%	81%	78%	89%	55%	83%	66%	84%	65%	90%	78%	90%	55%
Seat Avail & Comfort	75%	74%	71%	79%	75%	89%	59%	82%	69%	80%	54%	86%	74%	89%	54%
Space for Bags	67%	64%	65%	73%	67%	84%	53%	71%	59%	74%	37%	77%	64%	84%	37%
Smooth & Quiet	65%	71%	66%	76%	70%	84%	54%	77%	62%	80%	50%	85%	67%	85%	50%
Heating & Air Con	70%	72%	69%	71%	70%	88%	44%	78%	57%	78%	38%	81%	60%	88%	38%
Lighting	74%	77%	75%	76%	75%	91%	61%	82%	68%	84%	56%	85%	71%	91%	56%
Inside Clean & Graf.	72%	77%	68%	81%	74%	92%	58%	84%	65%	87%	53%	92%	74%	92%	53%
Information	59%	66%	67%	73%	66%	76%	38%	74%	55%	78%	48%	84%	53%	76%	38%
Computer & Internet	46%	61%	49%	60%	54%	72%	12%	71%	50%	58%	30%	67%	55%	72%	12%
Driver/Staff	71%	77%	66%	-	72%	92%	65%	82%	69%	81%	59%	-	-	92%	59%
Environ Impact	66%	71%	60%	73%	67%	84%	44%	77%	58%	72%	43%	76%	62%	84%	43%
Toilet Avail & Clean	-	-	59%	-	59%	-	-	-	-	76%	27%	-	-	76%	27%
Ticket Purchase#	70%	-	-	-	70%	71%	69%	-	-	-	-	-	-	71%	69%
Food/Drink+	-	-	-	78%	78%	-	-	-	-	-	-	76%	76%	76%	76%
Personal Security^	-	-	68%	-	68%	-	-	-	-	72%	59%	-	-	72%	59%
Train Layout^	-	-	68%	-	68%	-	-	-	-	81%	53%	-	-	81%	53%
Overall Rating	71%	74%	68%	78%	73%	79%	37%	84%	62%	82%	48%	85%	73%	85%	37%

Notes: T/L Melbourne Trams and Sydney Light Rail; ^ Sydney Trains; + fast Manly ferry; # onboard Melbourne ticket purchase

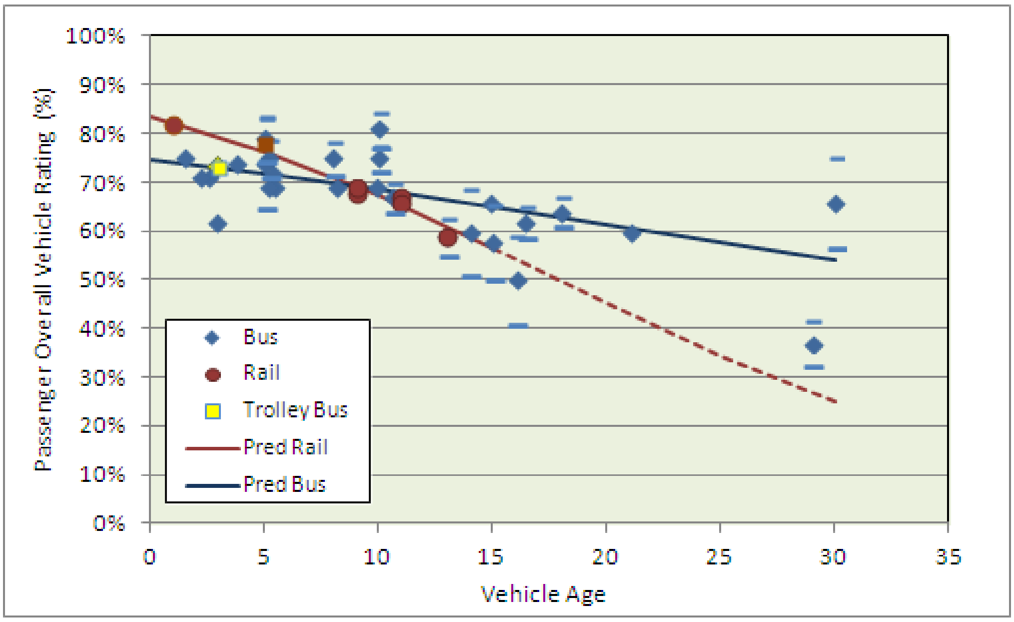
Sydney Ferries were the highest rated vehicles with an average overall rating of 78%. Trams/Light Rail were second on 74%. Buses averaged 71% with rail the lowest rated on 68%. The simple average rating for the four modes was 73%.

The large NZ sample and the recording of bus details enabled explanatory models to be fitted to explain the variation in vehicle ratings in terms of vehicle age, seat capacity, euro engine rating, air conditioning, floor height, wheelchair access, bicycle racks and premium branded bus routes. In addition, the characteristics of the passenger and the trip were also taken into account. The main report summarises some of the study findings.

The analysis established how vehicle age reduced the passenger rating. A new bus rated at 75% but after 5 years it declined to 72%, 67% after 10 years and 65% after 15 years. For trains, the decline was more pronounced falling from 84% for a new train to 76% after 5 years and 67% after 10 years. It should be noted here however that apart from the Wellington Matangi train which was new when surveyed, train age was measured from the year of last major refurbishment since Auckland and long distance Wellington rolling stock was imported second hand and majorly refurbished.

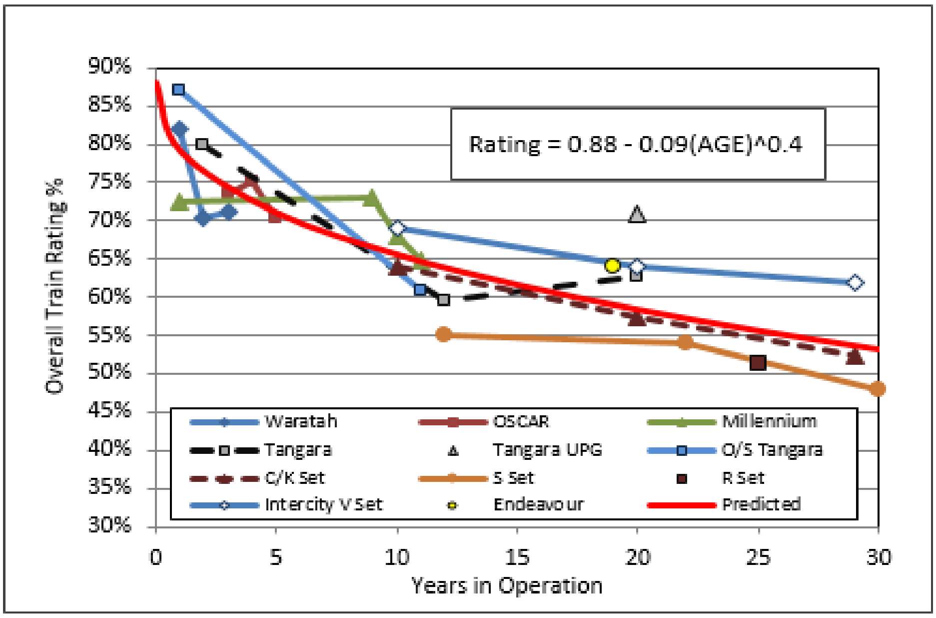
Figure 3: Effect of Vehicle Age on Bus and Train Overall Passenger Rating

2012-2014 Auckland, Christchurch and Wellington Survey



RailCorp NSW surveys which had been overtaken for more than two decades enabled the rating for an individual train type to be tracked over time in contrast to the cross-sectional NZ data. Figure 4 plots the decline in train rating with age for individual train types.

Figure 4: Effect of Age on the Passenger Rating of Sydney Trains



Age Yrs	0	5	10	15	20	25	30
Rating	88%	71%	66%	62%	58%	56%	53%

The decline in rating was steep over the first few years but then slackened off. The predicted rating for a brand new train was 88%. The rating then declined to 71% after 5 years and to 66% after 10 years.

By applying the three step valuation approach it is possible to convert the downward trend in ratings into a passenger disbenefit.

As well as vehicle age, the main report provides some examples of the value of difference in vehicle quality. Table 7 presents a summary. More commentary is provided in the Main Report.

Table 7: Estimates of the value of vehicle quality

Mode	Comparison	Comparison			Trip Length	Rating		IVT Valuation	
		A	B	Rating		A	B	mins per trip	Percent of IVT
Rail	Wellington New v Old	Matangi	Ganz Mavag	Overall	30	82%	59%	3.74	12.5%
	Sydney Suburban New v Old	Waratah	C/K Set	Overall	30	73%	54%	3.19	10.6%
	NSW Intercity Trains	OSCAR	V Set	Overall	90	72%	62%	4.26	4.7%
	NSW Tangara Refurbish	Refurb	Unrefurb	Overall	30	71%	63%	1.32	4.4%
	Electric v Diesel	WEL Sub Rail	AKL Rail	Overall	30	78%	67%	1.81	6.0%
				Environmental	30	69%	53%	0.40	1.3%
	Onboard Info Display (VIC,NZ,NSW)	4 Ests (1)	4 Ests (1)	Information	46	76%	55%	0.46	1.0%
	Air-Conditioning 2 Ests	NSW C&K & WEL G.Mavag	NSW S Sets & WEL Matangi	Heating & Air Conditioning	30	67%	47%	0.55	1.8%
	Security CCTVs NSW	Waratah	Tangara & CK&S Sets	Personal Security	30	80%	67%	0.30	1.0%
	Onboard Staff NZ	WEL with ticketing staff	AKL with guards	Staff Avail & Helpfulness	30	76%	68%	0.31	1.0%
	Newer Toilets NSW	OSCAR	V Set	Toilet Avail/Clean	90	58%	27%	0.66	0.7%
Tram	Old v New Tram VIC	E Class	Z Class	Overall	20	77%	62%	1.34	6.7%
	Onboard Next Stop Info Display VIC	A,B	C,D,E	Information	20	74%	55%	0.36	1.8%
	Onboard Staff NSW LRT cf VIC Tram	NSW LRT	VIC Tram	Staff Avail & Helpfulness	20	82%	71%	0.52	2.6%
	Low Floor VIC	CDE Class	Z Class	Ease of On/Off	20	82%	67%	0.15	0.8%
Bus	New v Old Predicted Rating NZ	Brand New	20 Years old	Overall	23	75%	61%	1.37	5.9%
	Premium v Standard Routes NZ	AKL Loop & WEL Flyer	Standard Routes	Overall	23	79%	69%	0.95	4.1%
	Onboard Info NZ	AKL Loop & WEL Flyer	Standard Routes	Information	23	78%	54%	0.32	1.4%
	Trolley vs Diesel NZ	Trolley Bus	Average Diesel Bus	Overall	23	73%	70%	0.32	1.4%
				Environment	23	65%	60%	0.08	0.3%
	Engine Standard NZ	Euro 5	Pre Euro	Environment	23	64%	54%	0.15	0.6%
	Bus Size NZ	Std 45 seats	Midi 22 seats	Seat Av/Comf	23	75%	57%	0.38	1.6%
	Artic v Std NSW	Artic (M10)	Standard	Seating	23	76%	69%	0.11	0.5%
	Std vs Low Floor NZ	Low Floor	Std Bus	Ease of On/Off	23	77%	68%	0.14	0.6%
	Route Rating NSW	Highest	Lowest	Overall	23	85%	60%	2.39	10.4%
Ferry	Vessel Rating NSW	Fast Cat	Freshwater	Overall	30	84%	73%	2.52	8.4%
	Cleanliness	Cpt Cook Cat	Freshwater	Cleanliness	30	92%	76%	0.40	1.3%

(1) WEL Matangi v Ganz Mavag; NSW Wara v CK; NSW H v V; VIC Xtra v Comeng

S4 Value of stop/station quality

The same rating based approach is used for valuing bus and tram stops, rail stations and ferry wharfs.

The values are 'per passenger boarding'. To work out the total benefit, the values need to be multiplied by the number of passengers boarding at the stop or station in question.

Alighting passengers and passengers making transfers are also likely to benefit however. Some guidance regarding on the likely value is provided in the main report.

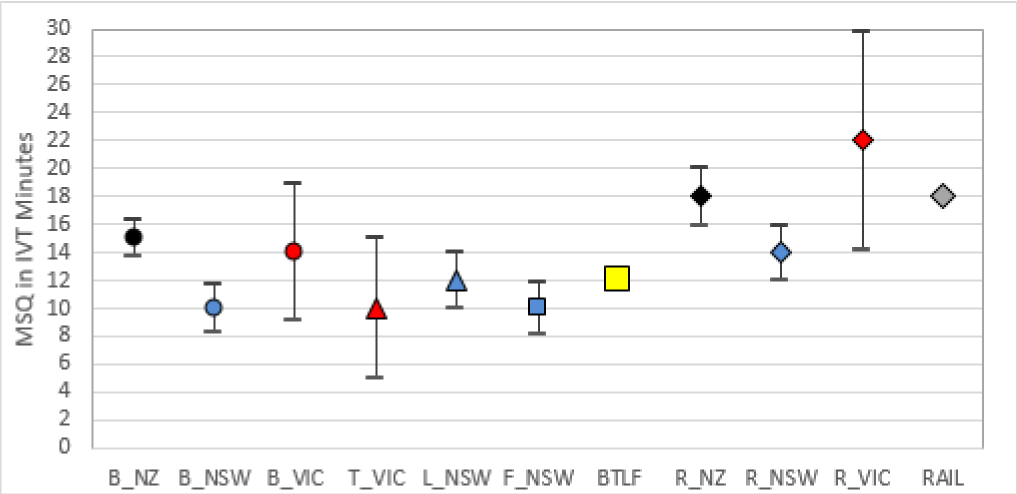
The bus and tram surveys featured a shorter list of stop attributes than rail stations and ferry wharfs which simply reflected the 'nature of the beast'. For bus stations, the values estimated for rail stations and ferry wharfs could be used.

Changes in overall stop/station/wharf quality were valued in equivalent in-vehicle time minutes. The NZ, NSW and Victoria surveys found the Maximum Stop Quality (MSQ) measuring the difference in WTP for a rating difference of 0% (very poor) to 100% (very good) to range from 10 to 22 minutes of IVT as Figure 5 shows. An MSQ of 12 minutes was considered appropriate for bus, tram, Light Rail and ferry and 18 minutes for rail.

As with vehicle quality it is highly unlikely that the maximum value of stop quality (MVS) will ever be realized and, like vehicle quality, a 40% to 80% change is more reasonable. Also like vehicle quality, the same transformation of the stop quality rating (power of 0.7) is applied to reflect the diminishing WTP for quality. The maximum is therefore effectively reduced to 33% of MSQ which is 4 minutes for bus stops, tram stops and ferry wharfs and 6 minutes for rail stations.

Figure 5 : Maximum Value of Stop, Station & Wharf Quality in IVT Minutes – Boarding Passengers

Mean estimate and 95% confidence range



When changes to individual stop attributes need evaluation, then as with vehicle quality step 2a is needed which takes account of attribute importance.

For bus stops, weather protection, seating, information and cleanliness each explained between a fifth to a quarter of the overall stop rating. Lighting was around 10%. For tram and LRT stops, ease of ticket purchase accounted for 10% which reduced the importance of the other attributes.

For ferry, ease of boarding and alighting was the most important wharf attribute at 20% followed by cleanliness and graffiti (17%) and weather protection (16%).

The longer list of attributes (Sydney rail covered 20 attributes) reduced the importance of individual attributes. Compensating the long list was the larger MSQ (18 versus 12 minutes). Of the attributes, only cleanliness / graffiti and information accounted for more than 10% each. The importance of weather protection dropped to 6%.

As with vehicle attribute ratings, a set of 'indirect' halo effects were developed (for NSW) to take account of the positive correlation between attribute ratings.

As a way of benchmarking the change in stop or station rating a particular proposal might have, the main report summarises the ratings of 28,677 passengers for 376 stops/stations.

Table 8 shows that the average rating was 68%. Bus stops rated the lowest on 64% then rail stations on 66%. Tram/LRT stops averaged 68% with Sydney ferry wharves rating the highest on 74%. The range in the rating at 10% points was therefore quite narrow (64% to 74%).

There was much wider range in the minimum and maximum ratings. The widest was for rail which ranged from 25% for Ava station in Wellington to 88% for Macquarie Park station in Sydney which had just been opened when surveyed. Averaging across the 4 modes gave a quality range of 40% to 83%.

Table 8: Stop, station and wharf ratings - NZ, Sydney and Melbourne (2009-2014)

Attribute	Average Rating					Bus		Tram/LRT		Ferry		Rail		Average	
	Bus	TrmL	Ferry	Rail	All	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Weather Protection	58%	64%	74%	65%	65%	13%	79%	40%	84%	64%	78%	33%	92%	38%	83%
Seating	58%	61%	68%	54%	60%	37%	76%	46%	75%	61%	75%	23%	78%	42%	76%
Information	65%	64%	73%	66%	67%	39%	84%	38%	75%	70%	75%	37%	85%	46%	80%
Lighting	65%	63%	76%	67%	68%	29%	78%	41%	82%	71%	79%	38%	92%	45%	83%
Cleanliness & Graffiti	63%	69%	78%	65%	69%	44%	86%	56%	91%	72%	82%	30%	90%	51%	87%
Ease of Ticket Purchase	na	53%	72%	63%	63%	na	na	20%	83%	44%	83%	9%	81%	24%	82%
Platform Surface	na	na	na	66%	66%	na	na	na	na	na	na	45%	87%	45%	87%
Platform Access	na	na	na	65%	65%	na	na	na	na	na	na	28%	87%	28%	87%
Ease of On/Off	na	na	81%	73%	77%	na	na	na	na	82%	84%	40%	85%	61%	85%
Toilet Avail/Clean	na	na	56%	45%	51%	na	na	na	na	44%	63%	4%	81%	24%	72%
Staff Avail/Helpfulness	na	na	74%	60%	67%	na	na	na	na	57%	78%	14%	83%	36%	81%
Retail/Food Drink	na	na	60%	53%	57%	na	na	na	na	25%	81%	3%	75%	14%	78%
Car Park/Pick Up	na	na	57%	56%	57%	na	na	na	na	48%	79%	27%	81%	38%	80%
Taxi drop off	na	na	na	57%	57%	na	na	na	na	na	na	34%	77%	34%	77%
Bus Transfer	na	na	73%	63%	68%	na	na	na	na	63%	79%	13%	78%	38%	79%
Bicycle Facilities	na	na	na	51%	51%	na	na	na	na	na	na	33%	83%	33%	83%
Design & Layout	na	na	na	65%	65%	na	na	na	na	na	na	41%	84%	41%	84%
Signage	na	na	na	66%	66%	na	na	na	na	na	na	46%	82%	46%	82%
Personal Security	na	na	na	64%	64%	na	na	na	na	na	na	40%	84%	40%	84%
Station telephones	na	na	na	58%	58%	na	na	na	na	na	na	43%	43%	43%	43%
Overall Rating	64%	68%	74%	66%	68%	46%	80%	36%	81%	54%	84%	25%	88%	40%	83%

'Ease of getting on and off the platform' was the highest attribute averaging 77%. Toilet availability and cleanliness and bicycle storage facilities were the lowest rated attributes (51%).

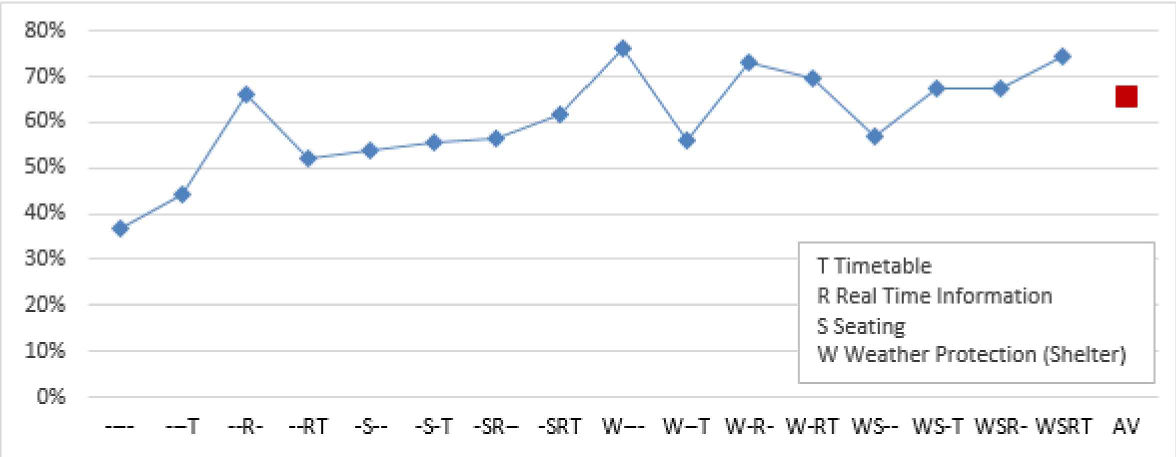
Seating (availability and comfort) rated the lowest (60%) of the five common attributes and cleanliness and graffiti was the highest rated (69%).

In terms of range, the lowest rating for bus stop weather protection (13%). For rail, weather protection achieved the highest rating (92%) and unsurprisingly, it was for the new underground rail station at Macquarie Park.

Bus and tram passengers in the NZ, NSW and VIC surveys were asked about the whether or not a timetable (T); electronic real time information (R); seating (S) and shelter (W) were provided at their stop. The large sample (5,157) provided response for all 16 combinations with the average rating graphed in Figure 6.

Applying the 3 step valuation approach to the ratings gave a value for the provision of shelter of 1.58 minutes for boarding passengers. RTI was valued at 1.01 minutes and a basic timetable 0.91 minutes. Seating had a low value of 0.27 minutes implying that most passengers must be happy to stand whilst waiting. Two additional tram attributes were also valued. A raised tram platform was worth 0.46 minutes and 'at-stop' Myki ticketing purchase/top-up facilities was worth 0.35 minutes.

Figure 6: Overall Bus and Tram Stop Rating with attribute provision



	----	---T	--R-	--RT	-S--	-S-T	-SR--	-SRT	W---	W--T	W-R-	W-RT	WS--	WS-T	WSR-	WSRT	AV
Rating	37%	44%	66%	52%	54%	56%	56%	62%	76%	56%	73%	70%	57%	67%	67%	74%	66%
Sample	171	284	24	94	46	383	25	167	32	124	8	47	149	1598	80	1935	5167

For rail stations, a comparison of the ratings of stations 'with and without' various attributes was undertaken.

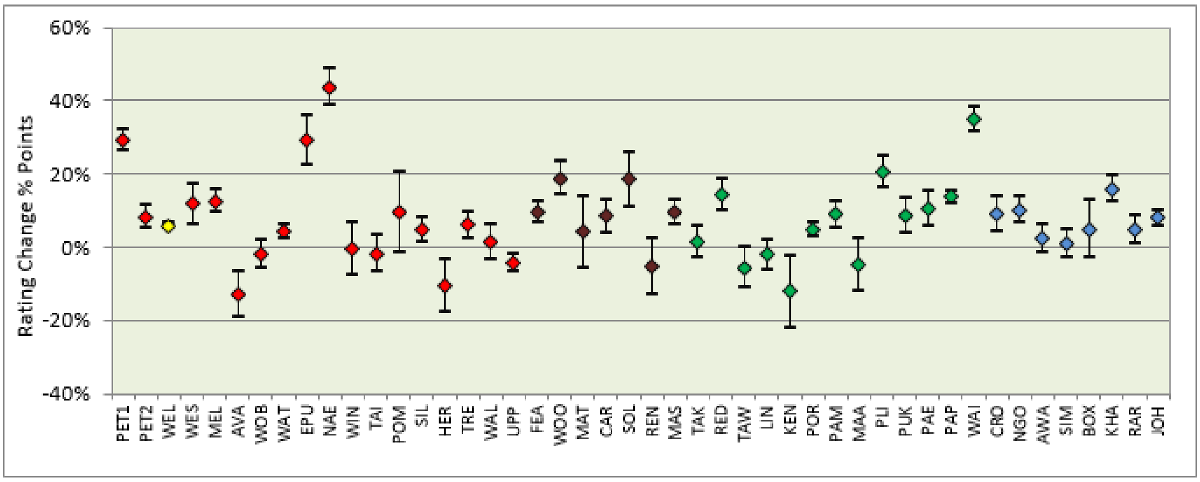
Table 9 presents the valuations expressed in IVT minutes for boarding passengers. The main report provides commentary on the valuations.

Table 9: Value of selected rail station attribute provision measured in IVT minutes per boarding trip

Attribute	Value Mins	Survey	Comment
Passenger Information Displays (PIDs)	0.59	VIC	Comparison of stations with/without PIDs (adjusted for more facilities at PIDs stations) for suburban trains.
Ticket Purchase Facilities	0.36	NZ	Calculated on difference in ticket rating at Wellington stations with/without ticket purchase facilities of 14% points.
Staff Presence	0.52	NZ	Calculated on difference in staff rating at stations with/without staff of 32% applied to overall rating for stations without staff of 56%.
Retail Facilities	0.30	NZ	Calculated on difference in retail rating for stations with/without of 32% applied to overall rating for stations without retail of 56%.
Toilets	0.31	NZ	Calculated on difference in rating of stations with/without toilets of 32% applied to overall rating for stations without toilets of 55%.
Provision of Lifts	0.60	NSW	Calculated on difference in platform access rating for stations with stairs with/without lifts of 36% applied to overall station rating of 60%
Ease of Bus Access	0.03	NZ	Calculated on difference in bus transfer rating for stations with/without of bus transfer of 32% applied to overall rating for stations without bus access of 56%.
Car Park / Drop Off	0.05	NSW	Calculated on difference in car park rating at stations with/without car parking of 9% applied to overall station rating for 60%
Bike Racks/Lockers	0.01	NSW	calculated on difference in bike rating with/without bike rack/locker of 4% applied to overall station rating of 60%
Taxi Rank	0.01	NSW	Calculated on difference in taxi rating at stations with/without taxi rank of 32% applied to overall station rating of 60%

For Wellington rail, passenger rating surveys of stations carried out a decade a part enabled the effect of station upgrades to be assessed using a regression analysis. Figure 7 shows the change in overall station rating for each of the 46 stations in the Wellington network. There was a general increase of around 5% but much bigger increases occurred at stations that had had major upgrades that involved rebuilding the main station. The biggest increases were for Naenae (40%) Petone (30%) and Waikanae station (35%) which were either totally rebuilt or majorly upgraded.

Figure 7: Change in overall station rating 2002/04 – 2012 for Wellington Rail stations.



A similar analysis was undertake for 48 NSW stations where there were sufficient observations in two surveys undertaken approximately 10 years apart. Figure 8 plots the results. A major upgrade increased the rating by 22% and an upgrade by 9% whereas at stations where no upgrade occurred the rating only increased by 2%.

As well as station upgrades, eight new stations were surveyed which had an average brand new rating of 88%. Applying the valuation approach estimated a new station would benefit station boarders by 5.1 minutes of IVT; a major upgrade by 3.7 minutes and a non-major upgrade by 1 minute. The benefit then declined to 4.1 minutes for a new station, 2.7 minutes for a major upgrade and to 0.3 minutes for an upgrade after 15 years.

The major upgrade value of 3.7 minutes was close to the NZ value of 4 minutes. Where they differed was in terms of the rate of decline with the NSW rate of decrease being flatter.

Figure 8: Change in NSW Station Ratings according to level of station upgrading

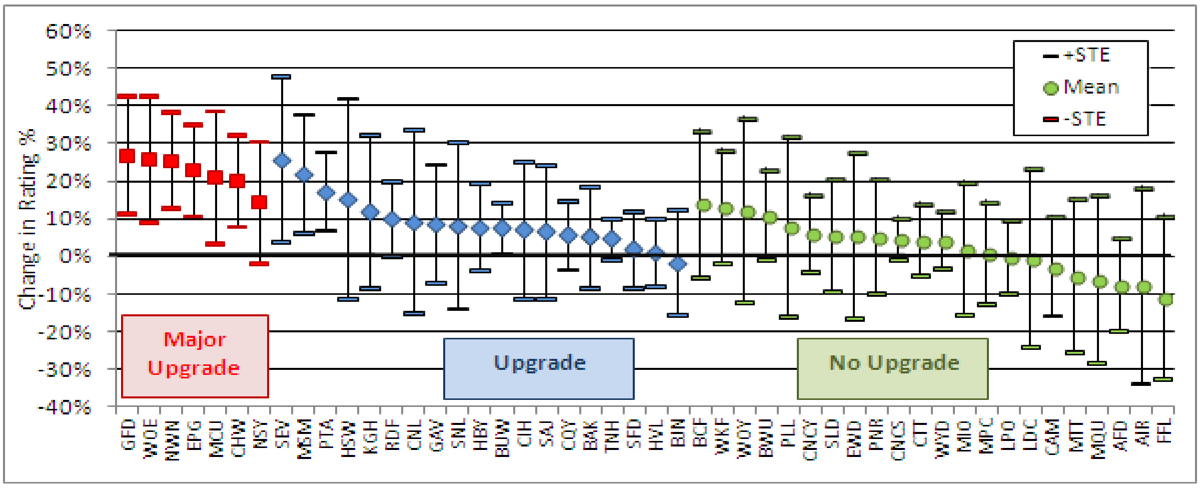
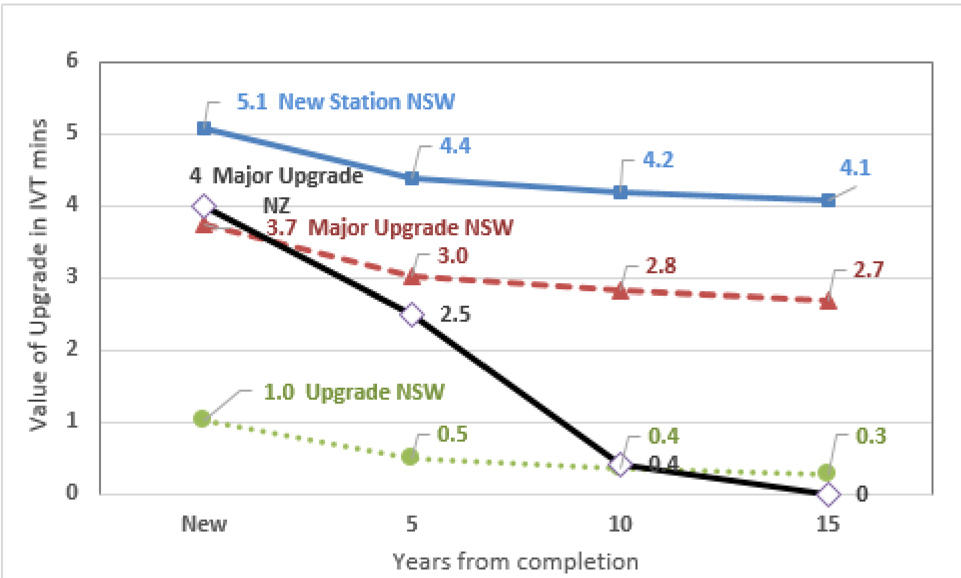


Figure 9: Value of New and Upgraded Stations

Valued in IVT minutes for boarding passengers



The Wellington survey data was used to estimate the passenger benefit of upgrading specific attributes such as platform shelter and seating. Table 10 presents the estimates. The main report provides some commentary on the estimates.

Table 10: Value of rail station upgrading to boarding passengers in IVT minutes

Upgrade	Attribute Rating Affected	Valuation		Comment
		Minor Upgrade	Major Upgrade	
Platform Shelter	Shelter	0.10	0.40	Based on predicted effect on weather protection rating
Seating	Seating	0.14	0.40	
Platform Surface	Platform Surface	0.17	0.39	Major upgrade included rebuilding platforms with access paths to 'street'
" " "	Platform On/off	0.23	0.37	
Information	Information	na	0.27	
Lighting	Lighting	0.09	0.19	
Cleaning/Graffiti	Cleanliness/Graffiti	0.33	0.87	
Toilets	Toilet	na	0.03	
Retail	Retail	na	0.33	Opening of café/small shop on platform or near platform.
" " "	Staff	na	0.02	'Staff' presence from retail facility
" " "	Ticket Purchase	na	0.49	Ability to sell rail tickets from retail outlet.
Car Park	Car Access	na	0.20	Major upgrade of car parking area including resurfacing, lighting, signing and walkways.
Bus Facilities	Bus Access	na	0.01	Improvement of bus waiting area including shelter and signage.
Overall Station	**Sum of Attributes**	**1.05**	**3.96**	**Sum of individual valuations**
Station Upgrade	Overall Rating	1.06	3.99	Valuation of major upgrade on opening day, on year 5 and on year 10.
After 5 years	" " "	na	2.35	
After 10 years	" " "	na	0.36	

The approach can also be used to value the ‘disruption’ disbenefit to passengers during a station rebuild.

S5 Mode Specific Constants

Mode Specific Constants (MSCs) measure the residual difference in modal quality after differences in travel convenience notably access/egress time, in-vehicle time, service frequency, transfer, crowding, reliability and fare have been deducted. They are often used in multi-modal studies such as forecasting the patronage for new services.

Four MSCs were estimated from a review of 15 Australian and NZ studies.

Table 11 presents the MSC estimates which measure the additional cost in IVT minutes of travelling by bus versus the comparison mode. In the third column, a combined Bus-(Rail/LRT) MSC was estimated based on a regression analysis of the 31 observations taking account the trip length.

Table 11: Mode Specific Constants in IVT minutes

	Bus - Rail	Bus - LRT	Bus- (Rail/LRT)+	Bus - TW	Bus - Ferry
MSC mins	10	12	7	5	16
Bus IVT mins	33	28	30	40	40
MSC Multiplier	0.30	0.43	0.23	0.12	0.40

+ based on logistic regression

The predicted MSC for bus versus Rail/LRT is presented in Table 12 for different trip lengths.

Table 12: Bus – (LRT/Rail) gross Mode Specific Constant by trip length

Bus IVT mins	5	10	15	20	25	30	35	40	45	50	55	60
MSC (mins)	0.6	1.1	1.8	3.0	4.6	6.9	9.7	12.9	15.9	18.6	20.6	22.1
IVT multiplier	0.11	0.11	0.12	0.15	0.19	0.23	0.28	0.32	0.35	0.37	0.37	0.37

A Sydney 2013 study estimated the 'intrinsic' MSC for Rail/LRT versus bus after standardising for quality difference between the modes. For a 25-minute trip, the intrinsic modal preference was worth 2.7 minutes for LRT/rail over bus (with negligible difference between rail and LRT). Having established the intrinsic difference, the value from differences in stop and vehicle quality can be added. Table 13 presents the combined value of vehicle and stop quality.

Table 13: Value of vehicle and stop/station quality differences in IVT mins

Attribute	Valuation of Quality Rating (mins) for a 25 minute trip								
	40%	45%	50%	55%	60%	65%	70%	75%	80%
Vehicle	7.0	7.6	8.2	8.8	9.3	9.8	10.4	10.9	11.4
Stop/Station	7.4	8.0	8.6	9.2	9.8	10.4	10.9	11.4	12.0
Total	14.4	15.6	16.8	18.0	19.1	20.2	21.3	22.3	23.4

To illustrate the approach, a proposed LRT system for which the vehicle rating is expected to increase from 70% to 80% and the stop rating from 65% to 75% is assessed. The vehicle quality improvement (70% to 80%) would be worth 1 minute per trip (10.36 to 11.38) with the stop quality improvement (65% to 75%) worth 1.1 minutes (10.36 to 11.45). Therefore, the combined quality improvement on the existing bus service would be 2.1 minutes. The intrinsic MSC of 2.7 minutes is then added to get a gross MSC worth 4.8 minutes.

1. Introduction

This is a technical report on public transport parameter values and supports ATAP Part M1 Public Transport Guidance. The parameter values (values of in-vehicle time and travel time multipliers) are based on a review of 40 market research studies and model estimation studies undertaken in Australia and New Zealand between 1990 and 2013.[8] Reference is also made to an OECD review of convenience factors that was undertaken by Wardman (2014). A 2018 meta-analysis and synthesis of public transport customer amenity valuation research by De Gruyter et al which looks at 'soft' factors is summarised at the end of the vehicle and the stop quality sections. Table 14 lists the attributes covered by the review.

Table 14: Attributes reviewed

#	Service Attribute	Section
1	Value of in-vehicle time in dollars	2
2	Access walk time	3
3	Service Frequency (Wait Time & Displacement)	4
4	Travel Time Reliability	5
5	Crowding	6
6	Transfer Penalty and Wait Time	7
7	Vehicle Quality	8
8	Bus Stop & Train Station Quality	9
9	Mode Specific Constants	10

Thirty-three of the studies were undertaken in Australia and seven in NZ. Most (25) of the Australian studies were undertaken in NSW (all except one in metropolitan Sydney). Eight of the Australian studies were undertaken outside NSW. Of these, two were undertaken in Brisbane/SE Queensland, three in Victoria, one in Perth, one in Canberra and one 'capital cities' study.

All but two studies were Stated Preferences (SP) market research surveys about *'what people say they would do'.* Only two studies were based on Revealed Preferences (RP) (i.e. *'what people actually do').* The two RP studies were calibration analyses for the Sydney Travel Model which used Household Travel Survey data.

Many of the SP studies were undertaken as part of forecasting the demand for a new service such as a light rail or a bus rapid transit. Other surveys were part of building demand models or estimating parameters for economic evaluations.

While the studies cover, bus, rail, ferry, light rail and busway (the latter only as a forecast mode), rail studies were predominant. Most surveys only interviewed users of the mode 'in question' but some surveys did interview car users and walkers/cyclists.

Typically, respondents were presented with a series of pair-wise choices that varied the times and costs. Usually, two public transport modes were compared such as bus versus bus or train versus bus. A few studies compared public transport with car or walk/cycle. Generally, those studies that

[8] Appendix Table 71 provides summaries.

presented 'same mode' choices (e.g. bus v bus) produced more precise estimates.[9]

For some attributes, the observations were weighted to reflect the relative accuracy of the study estimates.[10]

[9] Respondents in 'same mode' SPs were more likely to trade-off time with cost, varying their response across the choice situations whereas in 'between mode' SPs, respondents were more likely to stick to their current mode.

[10] The weights were based on the 't' statistic of the relative valuation. The t value is the ratio of the mean estimate to the standard error. Many studies reported t values for individual parameters such as fare or in-vehicle time but not for the relative valuation (the ratio of the estimates). Where possible, the t value for the relative value was calculated (assuming zero covariance between estimators). Where it was not possible to calculate, a value of 2 was assumed. To produce the weighting index, the t values were allocated to three categories and given a score of 1 for t values between 0 and 2, 2 for t values between 2 and 4 and 3 for t values exceeding 4. An average weight was then calculated whilst maintaining the number of observations. In general, the t statistic increased with the size of the sample but also reflected the design of the questionnaire, the composition of the samples and the survey method (self-completion, mail-back, interviewer led or internet survey).

2. Value of travel time

2.1 Introduction

The value of in-vehicle time (VOT) is an important parameter in computing generalised cost measures for patronage forecasts and project appraisal. The VOT enables travel times savings to be converted into dollars in order to compare travel time savings with project costs.[11] The value of in-vehicle time (IVT) also provides a base on which other travel time components such as access walk time can be monetised after applying 'IVT multipliers'. In this context the value of IVT time presented in this section, unless otherwise stated, is for seated onboard time on a bus, train or ferry for an average quality vehicle as perceived by users.

Thirty of the studies reviewed provided VOT estimates. Some studies provided estimates by time period (peak, off-peak and all) and some by travel mode (bus, LRT/tram, train and ferry). Altogether a total of 110 VOT estimates were provided.[12] The values were in market prices (i.e. inclusive of GST levied at the time).[13] Twenty-six of the studies were Australian (94 observations) and four were NZ (16 observations). Most of the Australian studies were undertaken in Sydney or NSW (20 studies and 69 observations).

The estimates covered a 24-year period from 1990 to 2014 and a key task was to take account of the year in which the studies were undertaken. As well as estimating a value of time for 2014, the review assessed the ability of three economic indicators to track the value of time and thereby provide a basis for updating the values from year to year and projecting the estimate through an appraisal period. The three indicators are: Consumer Price Index (CPI), Average Hourly Earnings (AHE)[14] and Gross Domestic Product.[15]

2.2 Trend in the value of time

Over the 25 years, the VOT for Australia increased from $4.75/hr in 1990 to $12.80/hr in 2014 as can be seen in Figure 10.

State as well as national estimates were assessed for GDP and AHE but gave a poorer fit although the analysis was compromised by the large proportion of NSW estimates in the dataset.

---

[11] Other components, such as access time, can also be converted in dollars after they have been expressed in equivalent in-vehicle time minutes.

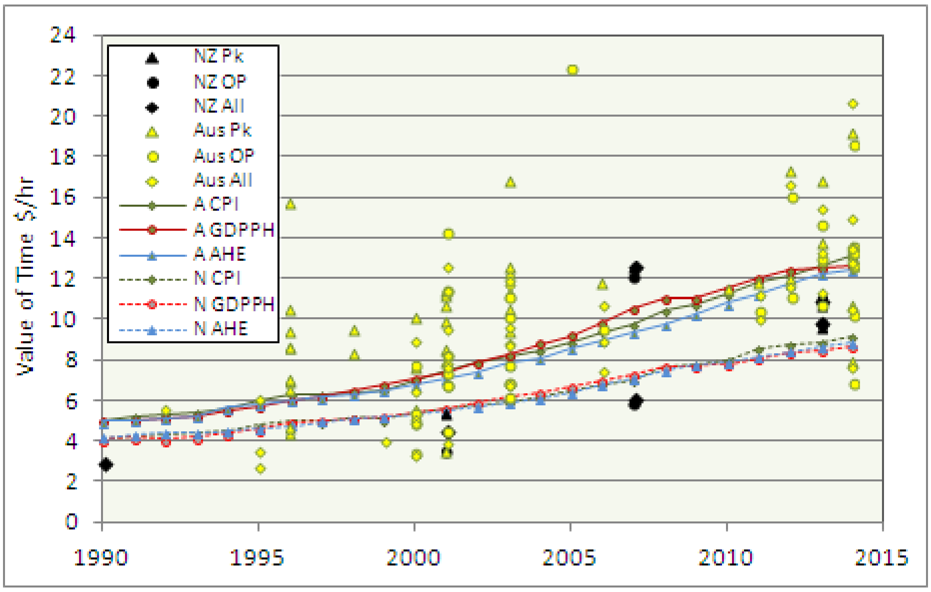
[12] Some studies produced estimates by trip purpose rather than peak/off-peak values. Where this was done, commuting to work trips were considered as peak and 'other' trips as off-peak with overall estimates treated as 50% peak and 50% off-peak.

[13] The values are also expressed in 'market prices'. All the estimates are based on a 'trade-off' between travel time and fare and the fare includes Goods and Service Taxation (GST) when levied. It should be noted that before 2000, there was no GST in Australia. Since 2000, a 10% GST has been levied on public transport fares. In NZ, GST was set at 12.5% until 2010 when it was raised to 15%.

[14] Weekly Earnings divided by 38 hours per week.

[15] The use of 2,000 hours which is approximately 38 hours x 52 (1,976) puts the GDP figure on a comparable basis with the value of time and also hourly earnings. It is only a relative positioning factor however. If annual figures were used the regression parameter for GDP would have been 7.6 times smaller (the natural logarithm of 2000).

Figure 10: Trend in the value of public transport in-vehicle time $/hr



Note: Australian values of time in Australian dollars and NZ in NZ dollars

GDP is normally reported in constant prices since it measures changes in output. However, as the 'observed' VOTs reflect changes in prices, GDP in current (nominal) prices was used. Models in constant prices were also fitted with GDP expressed in constant 2014 prices. A GDP deflator was used for GDP and CPI was used for AEH. Constant elasticity models[16] were fitted as shown in equation 2.1.[17]

$$\ln(VOT) = \beta_o + \beta_x \ln(X) + \beta_{bus} BUS + \beta_{ferry} FERRY + \beta_{OP} OPK + \beta_{NZ} NZ \qquad .....(2.1)$$

Where:

X = economic index (CPI, GDPPH or AHE)

$BUS, FERRY, OPK, NZ$ = variables classifying observations by mode, time period and country with rail, peak and Australia the base categories

$\beta_o, \beta_x, \beta_{bus}, \beta_{ferry}, \beta_{OP}, \beta_{NZ}$ = estimated parameters.

Table 15 presented the estimated models. Using current prices gave a better fit than constant prices (adjusted R2 of 0.63 versus 0.39). There was less different between the economic indices

---

[16] Logarithms of the VOT and economic indicator (X) were taken to transform the model into a linear form. The model can be rewritten multiplicatively by taking the exponential of the constant and classificatory variables regression coefficients ($\phi_i = \exp \beta_i$) so that $VOT = (\phi_o.\phi_{bus} BUS.\phi_{ferry} FERRY.\phi_{op} OP.\phi_{nz} NZ).X^{\beta x}$.

[17] Classificatory variables were specified as 'dummy' variables (1 if true 0 if false). It was not possible to classify all the observations into a category so probabilities were used (e.g. 'all' time period observations were classified as 0.5 peak and 0.5 off-peak. Other variables were tested. For example, some studies gave values for car users but the values of time were not significantly different from rail users. Some studies gave study type (SP v RP). However, none of the classificatory variables produced an improvement in goodness of fit to warrant inclusion.

which reflected the high correlation between CPI, AEH and GDPPH).[18]

The estimated elasticity for nominal GDPPH was slightly less than proportional (0.91) reflecting the slightly greater increase in GDPPH (a near tripling over the 24 years) than observed VOT.[19] By contrast, CPI inflation increased less over the period (190%) so the VOT elasticity, at 1.59, was greater. The increase in AHE at 240% fell midway between CPI and nominal GDPPH and the VOT elasticity was close to proportional at 1.07. Updating VOT proportional to AHE (i.e. parameter of 1) is supported by the analysis with Model 8 presenting the parameters with this constraint imposed.

Table 15: Value of time regression models

	Model X Statistic Prices Deflator Constrained	1 CPI Nat Current na	2 GDPPH Nat Current na	3 GDPPH State Current na	4 AHE Nat Current na	5 AHE State Current na	6 GDPPH Nat Constant GDP	7 AHE Nat Constant CPI	8 AHE Nat Current na Yes
Reg Coeff-icient	Constant	1.790	-0.483	-0.517	-0.892	-1.167	-0.349	-1.329	-0.686
	X	1.590	0.910	0.927	1.073	1.156	0.878	1.200	1.000
	Bus	-0.259	-0.251	-0.272	-0.259	-0.263	-0.251	-0.170	-0.269
	Ferry	0.254	0.269	0.266	0.263	0.226	0.269	0.264	0.233
	OffPk	-0.173	-0.180	-0.170	-0.171	-0.167	-0.183	-0.259	-0.152
	NZ	-0.124	ns	ns	-0.254	-0.242	ns	-0.251	-0.236
t value	Constant	27.6	2.1	2.0	3.3	3.9	0.7	1.5	16.4
	X	12.4	12.8	11.3	12.3	12.1	5.7	4.4	na
	Bus	4.5	4.4	4.5	4.5	4.6	4.4	4.5	4.60
	Ferry	2.8	2.9	2.7	2.9	2.4	2.9	2.9	2.50
	OffPk	3.0	3.1	2.8	3.0	2.9	3.2	2.9	2.60
	NZ	1.9	ns	ns	4.0	3.7	ns	3.9	3.60
Model Fit	Adj R^2	0.64	0.62	0.57	0.63	0.61	0.41	0.39	0.61
	Obs	132	132	132	132	132	132	132	132

State figures as well as national figures were fitted for GDP and AEH but goodness of fit worsened. Here, the dominance of NSW with three-quarters of the VOT observations should be noted. For NZ, a 'positioning' variable allowed for currency differences. For the GDP models, the coefficient was not statistically significant and was omitted. For the CPI and AEH models, the NZ coefficient was significant and implied a lower value of time than for Australia (for a given level of CPI or AEH).

2.3 Values of time for 2019

The predicted values of time for 2014 were estimated by time period (peak and off-peak). The peak and off-peak values were averaged to calculate an overall VOT.

[18] The correlation coefficient was 0.93 for GDP & AEH, 0.98 for GDP & CPI and 0.98 for AEH and CPI (log variables).

[19] The parameter was not significantly different from one: $((\beta_x - 1)/ste(\beta_x) = 0.05)$. A constrained model was fitted in which the GDP coefficient was set to 1. Unsurprisingly, the constraint had little effect on the other parameters.

The values by mode weighted by patronage share using BITRE for Australia and NZ DoT data for NZ to derive an overall average as given in Table 16.[20]

Table 16: Travel mode weights

Country	Trips (Australia) / Boardings (NZ) share				
	Rail	Tram/LRT	Bus	Ferry	All
Australia	43.0%	12.3%	43.3%	1.4%	100%
NZ	16.8%	na	79.3%	4.0%	100%

Source: Australia BITRE Report 129 Table 2.1 figures for 2010, NZ DoT TV020 figures for 2013/14

Similar VOTs for 2014 were forecast as can be seen from Table 17. For Australia, the overall VOT ranged from $12.60/hr to $13.10/hr with an average of $12.80/hr. For NZ, the average was $8.90/hr.

There are a range of approaches to update the value of time. An important deciding factor on what index to use is whether the updating is to a new 'base' year or whether it is to project the value of time through an evaluation period.

To update the value to a base year, the indices used should be in current prices (nominal or prices of the day) whereas for projecting the value through an evaluation period, the indices should be in real (constant or inflation adjusted prices)

Figure 10 and Table 15 showed the value of time to increase well above consumer price inflation over the 24-year period and so an 'elasticity' above one was needed. Nominal wage rate and National GDP per capita were closer (and thus needed an elasticity closer to 1).

Wage rates have been used to update values of time in some Australia jurisdictions. The UK has used GDP per capita with GDP expressed in current prices (i.e. not the GDP measure commonly reported by the media which is 'deflated' for price inflation).

If the value of time is projected to rise in real terms through the evaluation period (rather than remain constant) then either real wages or real GDP per capita could be used. Capital and operating costs should be treated in a consistent manner however.

[20] For tram/LRT studies 38 and 39 were used which gave a value of time 90% that of rail and 120% of bus.

Table 17: Value of time estimates

	Model Locality Prices Deflator	1 CPI Nat Current na	2 GDPPH Nat Current na	3 GDPPH State Current na	4 AHE Nat Current na	5 AHE State Current na	6 GDPPH Nat Constant GDP	7 AHE Nat Constant CPI	8 AHE Con Nat Current na	9 Av VOT Models 1,2&4
2014	**Aus (X)**	1.85	34.15	34.15	29.60	29.60	34.15	29.60	29.60	na
Peak	Rail	15.90	15.30	15.70	15.50	15.60	15.70	15.40	14.90	15.60
	Tram	14.50	14.00	14.30	14.20	14.20	14.40	14.70	13.50	14.20
$/hr	Bus	12.20	11.90	12.00	12.00	12.00	12.20	13.00	11.40	12.00
	Ferry	20.50	20.10	20.50	20.20	19.60	20.50	20.10	18.80	20.30
	Overall	14.20	13.70	14.00	13.90	13.90	14.10	14.30	13.30	13.90
Off-Pk	Rail	13.30	12.80	13.30	13.10	13.20	13.00	11.90	12.80	13.10
	Tram	12.20	11.70	12.00	11.90	12.00	11.90	11.30	11.60	11.90
$/hr	Bus	10.30	10.00	10.10	10.10	10.20	10.10	10.00	9.80	10.10
	Ferry	17.20	16.80	17.30	17.00	16.60	17.10	15.50	16.20	17.00
	Overall	11.90	11.50	11.80	11.70	11.80	11.70	11.10	11.40	11.70
Overall	Rail	14.60	14.10	14.50	14.30	14.40	14.40	13.70	13.90	14.40
	Tram	13.40	12.90	13.20	13.10	13.10	13.20	13.00	12.60	13.10
$/hr	Bus	11.30	11.00	11.10	11.10	11.10	11.20	11.50	10.60	11.10
	Ferry	18.90	18.50	18.90	18.60	18.10	18.80	17.80	17.50	18.70
	Overall	13.10	12.60	12.90	12.80	12.90	12.90	12.70	12.40	12.80
2014	**NZ (X)**	1.67	24.42	24.42	28.47	28.47	24.42	28.47	28.47	na
Peak	Rail	12.00	11.30	11.50	11.60	11.70	11.70	11.50	11.30	11.60
$/hr	Tram	na	na	na	na	na	na	na	na	na
	Bus	9.30	8.80	8.80	8.90	9.00	9.10	9.70	8.70	9.00
	Ferry	15.50	14.80	15.00	15.00	14.70	15.30	14.90	14.30	15.10
	Overall	10.00	9.50	9.50	9.60	9.70	9.80	10.20	9.40	9.70
Off-Pk	Rail	10.10	9.40	9.70	9.70	9.90	9.70	8.80	9.70	9.70
$/hr	Tram	na	na	na	na	na	na	na	na	na
	Bus	7.80	7.30	7.40	7.50	7.60	7.60	7.50	7.40	7.50
	Ferry	13.00	12.40	12.70	12.70	12.40	12.70	11.50	12.30	12.70
	Overall	8.40	7.90	8.00	8.10	8.20	8.20	7.90	8.00	8.10
Overall	Rail	11.10	10.40	10.60	10.70	10.80	10.70	10.20	10.50	10.70
	Tram	na	na	na	na	na	na	na	na	na
$/hr	Bus	8.60	8.10	8.10	8.20	8.30	8.40	8.60	8.10	8.30
	Ferry	14.30	13.60	13.90	13.90	13.60	14.00	13.20	13.30	13.90
	Overall	9.20	8.70	8.80	8.90	9.00	9.00	9.10	8.70	8.90

The 2014 values have now also been indexed to 2019 dollars. The 'average' values are given in Table 18 alongside peak and off-peak travel.[21] The overall average of $14.20/hr was 43% of AHE for Australia[22] and 37% of GDPPH and is an increase of $4.20/hr on the $10/hr figure in the 2006 ATC Guidelines.[23] For NZ, the average value of $9.90/hr represents 36% of AHE and 31% of GDPHH.

For updating purposes, the 'X' coefficients (which are also elasticities) for the alternative economic indices in Table 15 could be used.[24]

Table 18: Average value of public transport in-vehicle time

Values in national currency (Australian or NZ dollars) in 2019 prices and include GST

	Aus (A$)	NZ (NZ$)
Peak	15.40	10.80
Off-Peak	13.00	9.00
Overall	14.20	9.90

Some studies require values of time by mode. Table 19 presents guideline figures for Australia, the overall values were $16.00/hr for rail, $14.50/hr for tram/LRT, $12.30/hr for bus and $20.80/hr for ferry.

Table 19: Values of Public Transport In-vehicle time by mode

Values in local currency in 2019 prices and include GST

Time	Australia (Aus $)					New Zealand (NZ$)				
Period	Rail	Tram	Bus	Ferry	All	Rail	Tram	Bus	Ferry^	All
Peak	17.30	15.80	13.30	22.50	15.40	12.90	na	10.00	16.80	10.80
Off-Peak	14.50	13.20	11.20	18.90	13.00	10.80	na	8.30	14.10	9.00
Overall	16.00	14.50	12.30	20.80	14.20	11.90	na	9.20	15.40	9.90

^ no ferry services were surveyed in NZ

2.4 The effect of trip purpose on the value of time

Some demand forecasting models segment by trip purpose. Table 20 presents VOT by trip purpose based on the results of five studies: three Sydney studies (22, 38 & 40) one Melbourne (39) and one NZ (37). All four surveys had large sample sizes and covered both peak and off-peak

[21] Some of the studies included car users in the sample and the analysis was able to segment the results by user. The regression models did not find car users to be significantly different from rail users in their valuation of travel time.

[22] The Australian value is therefore close to the 40% wage rate assumption as recommended by the Austroads working group in 1997.

[23] The predicted VOT for 2006 was $9.40/hr.

[24] For projecting the value of time through an evaluation period, GDP per capita in constant prices could be used. This is the approach used by the UK Department of Transport which provides forecasts of GDP/capita for a 75 year period commenting "the Department uses HMT's GDP deflator, which is a much broader price index than consumer price indices (like CPI, RPI or RPIX) as it reflects the prices of all domestically produced goods and services. https://www.gov.uk/government/publications/webtag-tag-data-book .

travel. The VOT estimates have been expressed as a ratio of the average VOT. In the second row, a 'guideline' share for each trip purpose is presented (based on the average of the four studies).

Table 20: Effect of journey purpose on values of time

Ratio of trip purpose VOT to average VOT

Statistic	To/From Work	Educ-ation	Personal Business	Company Business	Shop-ping	Visiting Friends/ Relatives	Entertain-ment/ Holiday	Other	All
VOT/Av Ratio	115%	74%	95%	163%	93%	83%	89%	88%	100%
Trip Share	47%	17%	9%	2%	7%	8%	8%	2%	100%

Based on studies 22, 37, 38, 39 & 40.

The value of time for commuting to/from work was 115% of the average. Trips to/from school, college and university had a value of time 74% of the average.[25] Company business trips had the highest VOT at 163% of the average.[26]

2.5 TfNSW Value of Car & Public Transport Travel Time

Between 2012 and 2015, Transport for NSW (TfNSW) undertook a suite of Stated Preference (SP) surveys to estimate values of travel time (VOT) for public transport and car users. The principal aim was to test the 40% wage rate assumption that has been the basis for valuing private car travel time in NSW since the late 1990s.

At that time, TfNSW produced *'Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives'* (PGEATII). This report which includes a set of parameters for evaluating road and public transport projects. In terms of travel time, two sets of VOT are given dependent on whether the employer 'pays' for travel time (business travel) or whether the traveller pays (private travel).

The basic premise for business trips is that time spent travelling is unproductive with the 'opportunity cost' equal to the foregone working time and in PGEATII, business travel time was valued at $48.45/hr (2013/14 prices) based on 128% of average hourly earnings (AHE) comprising 135% of AHE less payroll tax of 7%.[27] For PT, the low share of company business trips (2% in Table 20) means that the company business value has little effect on the overall average.

[25] The value for education trips related to passengers over the age of 12 since younger school children were not surveyed (following market research protocol). For children travelling to/from school, the value of time probably reflects the 'willingness to pay' of the parents.

[26] Some studies use a wage rate plus on-costs value for company business trips representing the opportunity cost of travel time (for the employer). If a wage rate value is used, there is a question as to whether multipliers should be applied to walking time, waiting time, and other non IVT components to account for their greater relative disutility since an employee out of the office for an hour has the same wage cost to the employer irrespective of how much time is spent sitting on the bus or waiting at the bus stop. There may be productivity effects however that would not be reflected in the hourly wage.

[27] Business travel time includes travel for all modes, including taxi, hire and reward bus as well as light commercial, heavy rigid and articulated commercial vehicles.

TfNSW valued private travel time at 40% of Average Hourly Earnings (AHE) based on the recommendation of a 1997 Austroads workshop (Rainey, 1997) which reviewed international evidence and decided to adopt 40% of AHE for car, public transport (including waiting time), walking and cycling. On this basis, PGEATII valued private travel time at $15.14/hr (2013/14) based on a wage rate of $37.85/hr. The value compares with $8.90/hr for public transport given in Table 17. The survey estimate is therefore $6.24/hr less (-40%).[28]

TfNSW began a program of market research in 2012. Four surveys public transport surveys were undertaken. The largest used self-completion questionnaires handed out and collected by on-board buses, light rail, trains and ferries. The surveys adopted the same format and included five variables: in-vehicle time, frequency, vehicle quality, stop quality and fare. The other three PT surveys used interviewers with handheld computer tablets and additional attributes (interchange, travel time displacement, crowding and mode) and were undertaken in Inner Sydney.[29] The surveys were kept short and simple which enabled a large sample of 8,877 respondents and 71,000 choice observations to be achieved. [30]

The car SP survey took a year to develop and implement, starting with a literature review followed by sequential testing of 3 designs (including several variants). The final design included travel time variability with car drive time and cost and was carried out by interviewers at 6 activity centres using computer tablets.[31] In total, 613 interviews providing 4,722 choice observations were completed with most surveyed in early December 2015.

Table 21: Estimated Values of Time estimated by TfNSW 2015 Study

	Trip	SP Survey Values		Percent of	Income Standardised^
Mode	Share	Income $kpa	VOT $/hr	AHE #	VOT $/hr
Bus	43%	44.0	9.30	25%	12.07
LRT	1%	56.7	16.56	44%	16.47
Rail	53%	51.0	13.02	34%	14.22
Ferry	3%	73.0	14.19	37%	10.44
PT	15%	48.7	11.49	30%	13.20
Car	85%	57.7	14.63	39%	14.33
All	100%	56.3	14.16	37%	14.16

^ Income standardised values of time at $56,300 per year

40% of average hourly earnings = $15.14/hr (0.4 x $37.85/hr)

The average VOT for PT, taking account the market shares of the four modes, was $11.49/hr; this is $2.59/hr (30%) above the review estimate of $8.90/hr in Table 17.

The car value was $14.63/hr which was 27% higher than the PT value. Car's dominant share

[28] PGEATII has been renamed and updated as the NSW Cost Benefit Guide https://www.transport.nsw.gov.au/projects/project-delivery-requirements/evaluation-and-assurance/transport-for-nsw-cost-benefit

[29] Douglas and Jones (2018) provide a description.

[30] A longer description of the car survey is provided in Legaspi and Douglas (2015).

[31] The activity centres were in Parramatta, Bondi Junction, Chatswood, Hurstville, Newcastle and Wollongong.

(85%) meant that the overall average was heavily skewed towards the car VOT of $14.16/hr VOT.

All the surveys asked the respondent's income which enabled the values to be income standardised at the sample average income of the $56,000.[32] Income standardisation increased the bus and rail values but reduced the LRT, ferry and car values. The biggest impact was on ferry users with VOT reducing from $14.19/hr to $10.40/hr reflecting their relatively high incomes ($73,000). The second biggest impact was on bus users with VOT increasing from $9.30/hr to $12.07/hr reflecting their relatively low income of $44,000. The average VOT for PT increased to $13.20/hr whereas the car value changed little, dropping to $14.33 reflecting its high modal share. The weighted average remained at $14.16/hr (as it should do).

The weighted average VOT of $14.16/hr was a dollar lower than the $15.14/hr required for a 40% of AHE value ($37.85/hr). The 'percentage of the wage rate' was 37%.

Table 22 shows the car VOT at $14.63/hr to be very close to the required value, being 39% of AHE. Commuter drive time was $16.58/hr (44% of AHE) with other travel valued at $14.14/hr (37%).

Table 22: Estimated Values of Time by Trip Purpose by TfNSW 2015 Study

Trip	Value of Time $/hr			Percentage of Wage Rate^			Av. Income $000 p.a.		
Purpose	Car	PT	ALL	Car	PT	ALL	Car	PT	ALL
Commuting	16.58	14.98	16.13	44%	40%	43%	68	64	67
Other Trips#	14.14	8.94	13.57	37%	24%	36%	52	38	50
All	14.63	11.32	14.13	39%	30%	37%	55	48	54

^ Calculated as percentage of $37.85/hr. Car shares 72% commuting, 89% other and 85% overall.

Excludes trips travelling on company business

It should be noted that the values of time shown in Table 22 are behavioural values of time rather than resource values (see discussion in Part M1 section 5.1).

The PT values were lower than the required rate. At $10.32/hr, the average value was 27% of AHE. The commuting value at $12.38/hr was closer (33%) but for 'other' trip purposes the value was than a quarter of AHE at $8.66/hr (23%). This result is considered to reflect the lower incomes and a greater use of fare concessions.[33]

Response supported a 40% wage rate assumption for private travel time by car and for commuting trips by public transport. However a lower valuation of around a quarter the wage rate was estimated for non-commuting private travel trips by public transport. [34]

[32] Income standardisation is described in Douglas and Jones (2013) and Douglas and Jones (2018).

[33] The higher use of concession fares (49%) reduced the value of time for other trips (49%) compared to commuting (9%) because the time savings were bought at 'half the price'.

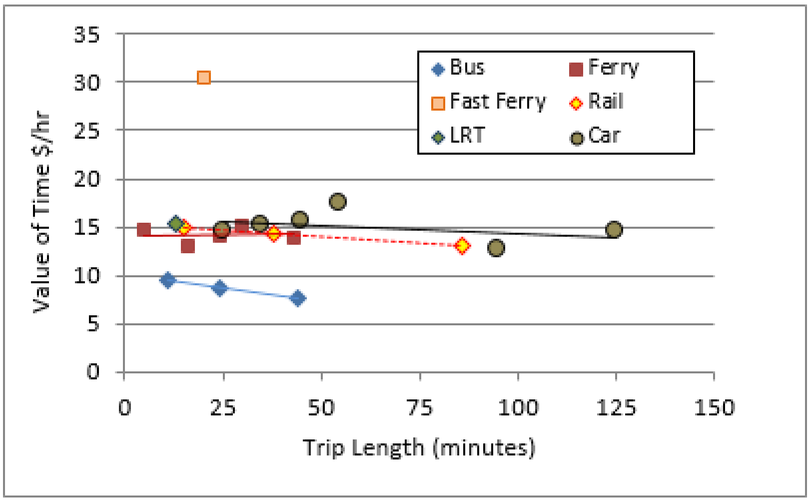
[34] The values are referenced in TfNSW 'Economic Parameter Values' 2020 in section A.2. TfNSW adopts the same 'equity' value of time for economic CBA purposes (but with multipliers applied to take account of effort/quality/reliability etc).
https://www.transport.nsw.gov.au/projects/project-delivery-requirements/evaluation-and-assurance/technical-guidance

A subsidiary aim of the TfNSW study was to test whether the value of time increases with trip length as has been argued by some researchers.

Short, medium, long questionnaires were developed in order to tailor the show cards to the trip the respondent was making, However the differences in the time and cost between the two options the respondent chose between were kept the same across all the trip lengths.

Respondents answering the long distance questionnaires tended to be less sensitive to the time and cost differences than respondents completing the medium and short distance questionnaires. However, the decline in sensitivity was roughly the same for time as it was for cost and this meant that the value of time (which is ratio of the two sensitivities) remained roughly the same.[35] Figure 11 plots the value of time estimates by distance for the different modes.

Figure 11: Value of Time with Trip Length – TfNSW 2015 Survey.



For car, ‘standard’ ferry, rail and LRT, the value of time was around $15/hr and was largely invariant with trip length. Fast ferry respondents at $30/hr had a much higher value of time which reflected ‘self-selection’ i.e. ferry users with a high value of time selected the fast ferry whereas those with a value of time of $15/hr travelled by the slower but cheaper standard Manly ferry.

Bus was the only mode where the value of time varied with trip length. However rather than increasing as some researchers such as Batley et al (2018) have argued, the value of time declined from $9.50/hr for short trips of around 10 minutes to $7.70/hr for long trips of around 40 minutes.

Overall, there was no evidence to support the value of time to increase with trip length.

[35] There was no evidence to support the sensitivity to cost to increase with distance as reported in the Sydney Strategic Travel Model, Fox et al (2015).

3. Walk (access/egress) time

Walk access/egress to and from bus stops, train stations and ferry terminals constitutes part of 'out of vehicle time' (OVT); the other part being waiting time. Given the extra effort involved in walking relative to sitting on a bus or train, transport models usually apply an IVT multiplier greater than one.

A total of 21 studies provided values for access/egress time relative to in-vehicle time. Of these, 18 were Australian studies (predominately NSW) and three were NZ. Altogether, the studies provided 49 values. Most of the studies were undertaken between 1995 and 2005. Some of the Australasian studies were not specific in terms of the type of access and egress that was measured lumping walking with car or referring to 'out of vehicle time' that included waiting at the bus stop.

The studies showed that access/egress was valued higher than seated in-vehicle time, but not markedly so. The average IVT multiplier was 1.32 with quite a wide scatter as Figure 12 and Table 23 illustrate.

Figure 12: Value of walk access /egress time

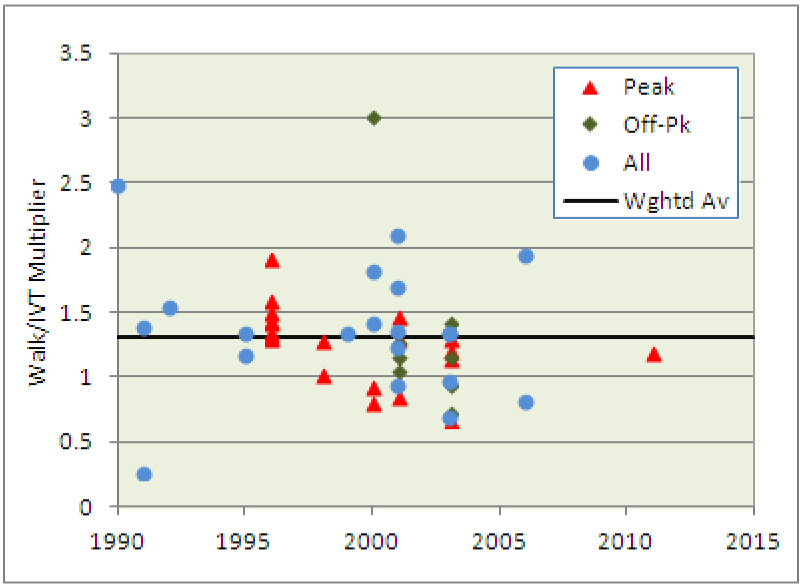


Table 23: Value of walk access /egress time

Minute of walk time in equivalent IVT minutes

Statistic	Peak	Off-Pk	All	Overall
Upper Quartile	1.42	1.30	1.59	1.42
Mean	1.30	1.27	1.26	1.32
Lower Quartile	1.11	1.02	1.12	1.04
Obs	20	8	20	48

All but two studies used Stated Preference (SP) market research and in this regard, it is worth mentioning a problem in getting respondents to think about bus stops and train stations located away from the ones they normally use. The two non-SP studies were calibrations of the Sydney Travel model in which the value of walk time was estimated cross-sectionally using household travel survey data. These two studies, based on actual behavior, gave a higher IVT multiplier of 1.5 which is close to the figure of 1.48 derived by Wardman (2001a) in a meta-analysis of 143 UK estimates largely undertaken in the 1980s and 1990s. The OECD Review by Wardman (2014) which includes studies undertaken outside the UK reports a higher value of 1.75 to 2.0 for walk/wait time with the recommended value increasing to between 2 and 3.5 for crowded situations and to 4.0 for situations demanding more than normal effect such as ascending stairs (see section 6.4 on station crowding).

Based on the Australasian evidence and taking into account the two reviews by Wardman, a figure of 1.5 for walk time is recommended for uncongested conditions and for 'normal effort'.

It is worth noting that, for many years, the convention was to use an IVT multiplier for walking time of 2.0. This origins for the multiplier of 2 dates back to a UK Department of the Environment Mathematical Advisory Note 179 by McIntosh and Quarmby in 1970. This should no longer be used.

4. Service interval, waiting time and displacement

4.1 Waiting time and service interval

The inability to travel when you want to due to timetable constraints is an inconvenience that car users typically do not face. The review looked at three inter-related timetabling issues: service interval, waiting time and travel time displacement. Service interval is the mirror image of service frequency and measures the number of minutes between departures: the higher the service frequency (buses per hour), the lower the service interval.

For high frequency services (more than 5 per hour or 12 minutes apart)[36], passengers tend to turn up ‘at random’ at the bus stop or train station. The average waiting time (assuming a regular service) for these people would be half the service interval.

Analysis of service interval and waiting time by Melbourne, Sydney and NZ PT users (studies 36, 37 & 38) supports this as can be seen from Figure 13. At a service interval of 14 minutes, the average wait time was exactly one half (i.e. 7 minutes).[37] At lower frequencies, the wait time flattened out so that for an hourly service, the average waiting time was just less than 15 minutes. The estimated relationship ($1.88\sqrt{SI}$) can be used to predict the waiting time for modelling and evaluation purposes given knowledge of the timetabled service frequency.

For high frequency services (service intervals less than 14 minutes), waiting times tend to be longer than half the service interval. For example, for a service every five minutes, the predicted waiting time was 4.2 minutes which is 84% rather than 50% of the SI. The longer wait may be due to ‘rounding up’ by respondents or service irregularity. The recommendation is therefore to assume half the service interval up to a service interval of 14 minutes. Then, for less frequent services, use 1.88 multiplied by the square root of the service interval up to a maximum predicted wait of 20 minutes (for a two-hourly service). Thus mathematically, the recommended wait time model is the minimum of half the service interval (headway), 1.88 times the square root of the service interval and 20 minutes as shown in equation 4.1.

$$WAIT = Min(0.5SI, 1.88\sqrt{SI}, 20) \quad .....(4.1)$$

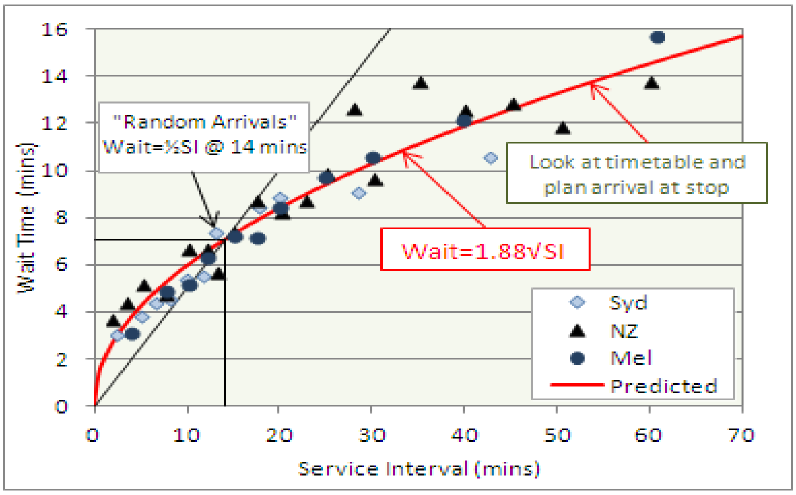
[36] London Transport uses a definition of more than 5 services per hour or an interval of 12 minutes or less.

[37] The square root function adopted means there are two solutions where wait time is half the headway $0.5SI = \alpha + \beta\sqrt{SI}$. The two solutions are $SI = 2\left(k \pm \sqrt{k^2 - \alpha^2}\right)$ where $k = \alpha + \beta^2$.

With $\alpha = 0$ and $\beta = 1.88$, the solutions are 0 and 14.1 minutes.

Figure 13: Relationship between wait time and service interval

Times as perceived by bus, train, tram and LRT users in Melbourne, Sydney and NZ



4.2 Average value of service interval/IVT

Thirty studies provided estimates of the relative valuation of service interval (SI/IVT). 25 studies were Australian (mainly NSW) and five were NZ. Table 24 summarises the ratio across the studies. Most were Stated Preference surveys that described services as ‘every X minutes’ with a few describing the ‘maximum wait time’.[38]

The mean valuation of SI was 0.64 with an inter-quartile range from 0.45 to 0.77.[39] The valuation for Australia was 0.66. For NZ, the value was lower at 0.51 reflecting the effect of studies undertaken in the 1990s with lower services.

Table 24: Value of service interval/IVT

Statistic	NZ	Aus	All
Mean	0.51	0.66	0.64
75% tile	0.68	0.79	0.77
Median	0.45	0.69	0.67
25% tile	0.38	0.45	0.45
Observations	13	102	115
Studies	5	25	30

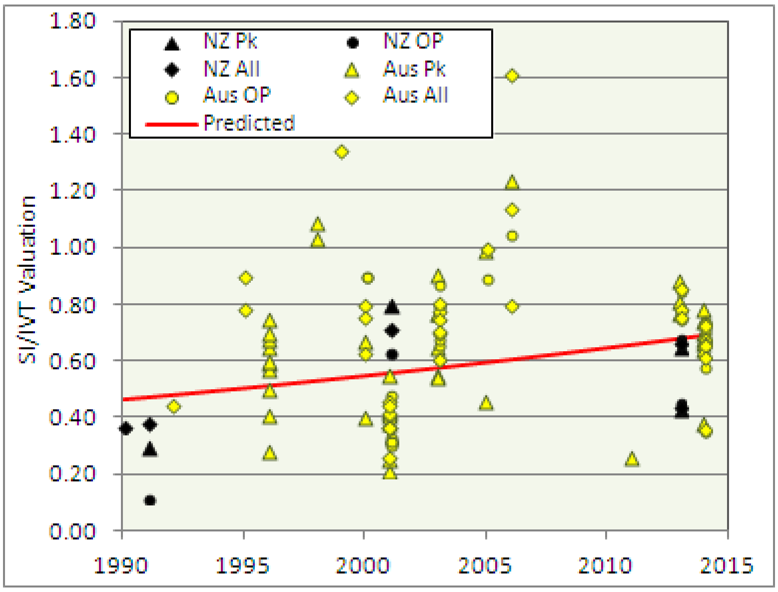
^ weighted in accordance with t value

Over the 2½ decades for which studies were reviewed, the SI/IVT value trended upwards as can be seen from Figure 14. Superimposed on the scattergram is a trend line which increased from 0.49 in 1990 to 0.69 in 2014. Based on the trend analysis, a guideline figure of 0.7 is suggested which is close to the recommendation of 0.71 given in the Wardman OECD review (2014).

[38] One survey measured ‘service displacement’ (the cost of not being able to travel at the desired time) and the resultant valuations low).

[39] The estimates in Table 24 were weighted according to the relative t value. Weighting had little impact however. Without weighting the mean value of SI was 0.65.

Figure 14: Increase in the valuation of service interval over time



4.3 Service interval function

Studies have shown that the relative valuation of SI/IVT varies with the frequency of service. For high frequency services, the valuation reflects the value of waiting time, whereas for low frequency services the value reflects displacement time. Two approaches were used to develop SI/IVT functions:

- Composite function based on five Australian and NZ studies
- Wait time and displacement valuations.

Six studies (2 NZ: 20 & 37 and four Australian: 28, 38, 39 and 40 estimated curvilinear SI/IVT functions whereby the valuation depended on the service interval itself. A composite function was estimated by regression that averaged the six functions.

Figure 15 presents the function (the dashed line) with a 'lookup' table alongside. For a high frequency service departing every 5 minutes, the tabulated SI/IVT valuation is 0.89. For a 20-minute service interval, which was the average across the six studies, the SI/IVT valuation is 0.68 and for an hourly service, the valuation is 0.35.

Equation 4.3.1 presents the equation to predict the SI/IVT multiplier:

$$SI/IVT = Min + \{Max - Min\}Z \quad .....(4.3.1)$$

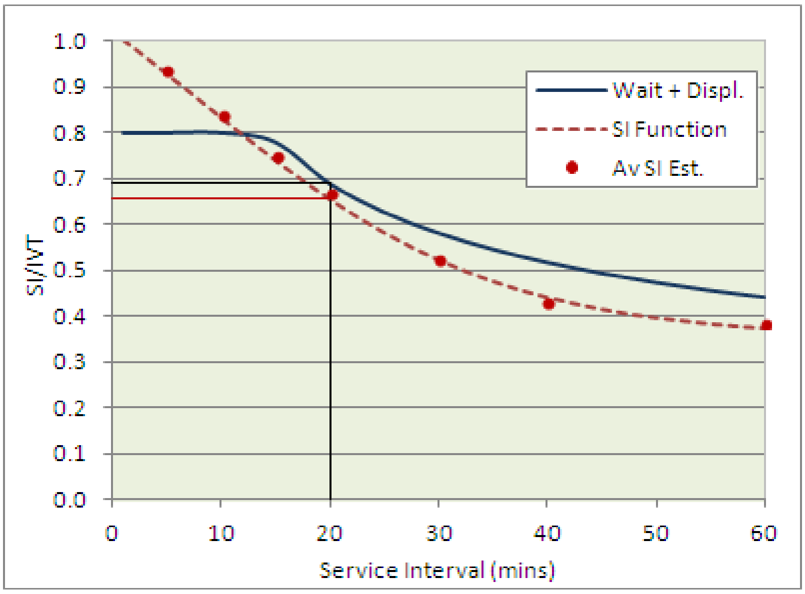
Where $Z = \dfrac{\exp(\alpha + \beta SI)}{1 + \exp(\alpha + \beta SI)}$

Max =maximum value of SI/IVT is 1.4

Min =minimum value of SI/IVT is 0.35

α = 0.57 & β = -0.07

Figure 15: Service interval /IVT function



SI	SI/IVT	
mins	SI Func	W+D
1	1.00	0.80
5	0.93	0.80
10	0.83	0.80
15	0.74	0.78
20	0.65	0.69
25	0.58	0.63
30	0.52	0.58
35	0.48	0.54
40	0.44	0.52
45	0.41	0.49
50	0.40	0.47
55	0.38	0.45
60	0.37	0.44

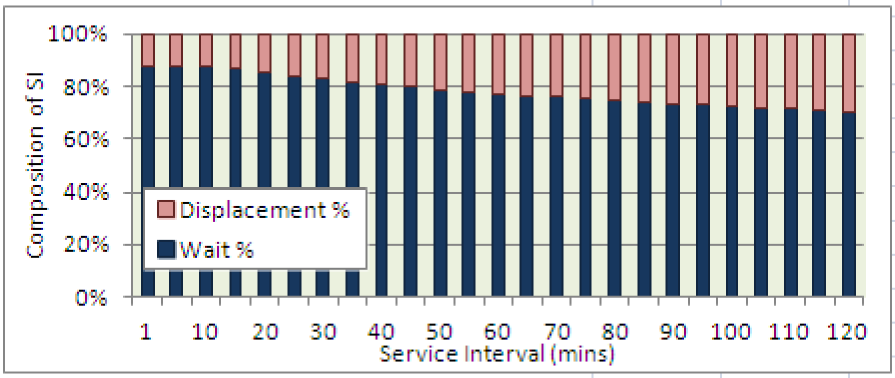
The alternative approach uses weighted waiting and displacement time. Theoretically, the SI/IVT value will depend on weighted waiting time (valued relatively highly) and timetable displacement time (valued relatively lowly). For high service frequencies, the SI/IVT will primarily reflect the wait/IVT valuation for which a relative IVT valuation of 1.4 has been used.

For less frequent services, the valuation of displacement (the cost of not being able to travel at the desired time) becomes important. The evidence is for displacement to be valued less than waiting time since it can be spent in the office, at home or down the pub rather than at a bus stop or train station. Section 4.4 reviews the value of displacement time. A multiplier of 0.1 has been used in Figure 15. Equation 4.3.2 shows the SI/IVT valuation function..

$$SI / IVT = \frac{1}{SI}\left[1.4\left\{Min\left(0.5SI, 1.88\sqrt{SI}\right), 20\right\} + 0.1SI\right] \text{.....(4.3.2)}$$

For service intervals under 15 minutes, the SI/IVT valuation (blue line in Figure 15) is constant at 0.8. The valuation then declines as waiting time becomes a smaller proportion of SI so that for an hourly service, the SI/IVT valuation is 0.44. For ten to 30 minute frequencies, the two approaches give similar SI/IVT multipliers. Figure 16 shows how the wait time value declines from 88% for a 5 minute service to 70% for a two hourly service.

Figure 16: Composition of service interval valuation



Of the two methods, the wait + displacement approach has appeal because it explains the valuation in terms of waiting time and displacement.

4.4 Valuing changes in service frequency

Using the estimated marginal service interval function does complicate calculations and for most applications, an average valuation could be used that is typical of the service frequencies on offer.

When large changes in service frequency are evaluated, the mid-point value between the 'before' and 'after' service intervals can be referenced in order to calculate an average value (from the marginal curve). Thus, as shown in Figure 17, to evaluate a frequency increase from every 40 to every 20 minutes (using the W+D function), the value at 30 minutes (0.58) is used which produces a benefit of 11.6 minutes. This is same as working out the area of the area of the trapezoid ABCDE.

Figure 17: Valuing a SI change

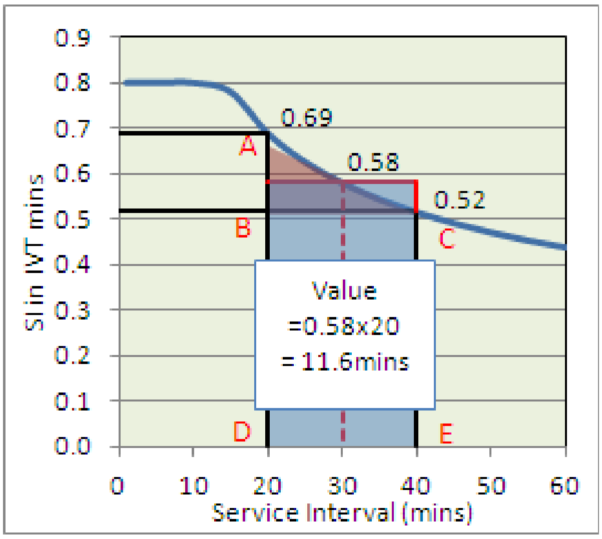
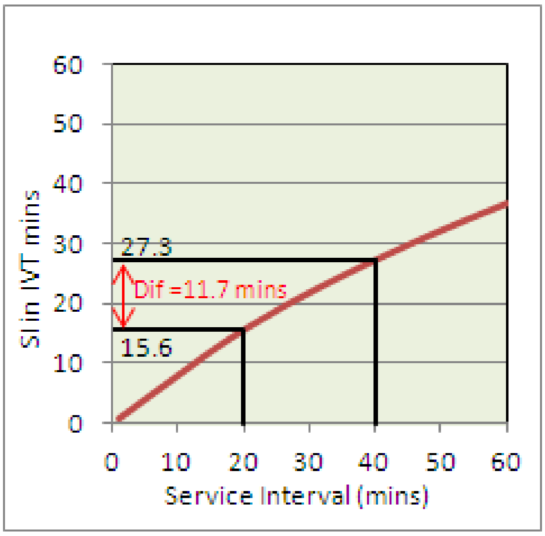


Figure 18: Cumulative SI function



A more accurate estimate taking the curvature of the SI function into account can reference Table 25 which gives cumulative values by SI minute. Thus for a 40 to 20-minute SI reduction, 15.6 minutes is subtracted from 27.3 minutes to give a benefit of 11.7 minutes (0.1 minutes more than using the mid-point value). Figure 18 shows the cumulative function.

4.5 Travel time displacement

Travel time displacement arises from not being able to travel at the desired time. Since travel time displacement represents part of service interval (as outlined in the previous section), the two measures should not be double counted.[40] Wardman (2014) notes that "whilst service frequencies can be readily observed and hence their use in generalized cost based applications is straightforward, this is not the case for displacement time where surveys are

[40] In fact, it can be shown that the displacement value should be divided by 4 to be equivalent to service interval.

needed on desired departure times to convert timetabled departures into displacement time". This task need not be unduly burdensome if station barrier data or vehicle load data to approximate the 'desired profile'. Figure 19 presents the barrier exit profile for Sydney rail users as an example.

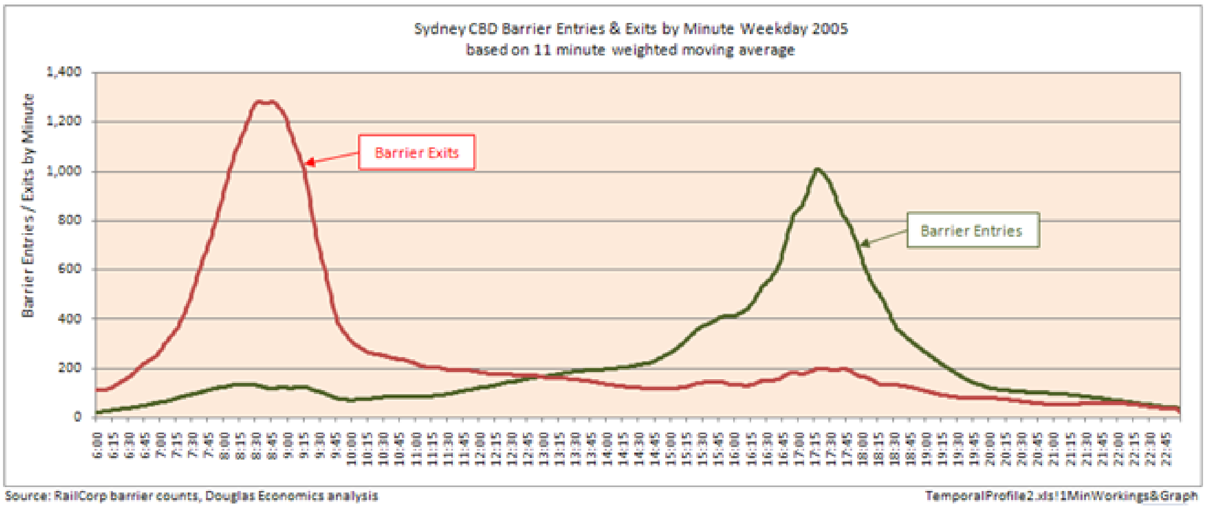
Table 25: Cumulative SI valuation function

SI interval in minutes and cumulative (total) valuation in IVT minutes

SI	CumV	SI	CumV	SI	CumV	SI	CumV	SI	CumV	SI	CumV
1	0.8	11	8.8	21	16.3	31	22.4	41	27.8	51	32.6
2	1.6	12	9.6	22	16.9	32	23.0	42	28.3	52	33.1
3	2.4	13	10.4	23	17.6	33	23.5	43	28.8	53	33.6
4	3.2	14	11.2	24	18.2	34	24.1	44	29.3	54	34.0
5	4.0	15	12.0	25	18.8	35	24.6	45	29.8	55	34.5
6	4.8	16	12.7	26	19.5	36	25.2	46	30.3	56	34.9
7	5.6	17	13.5	27	20.1	37	25.7	47	30.7	57	35.4
8	6.4	18	14.2	28	20.7	38	26.2	48	31.2	58	35.8
9	7.2	19	14.9	29	21.2	39	26.7	49	31.7	59	36.3
10	8.0	20	15.6	30	21.8	40	27.3	50	32.2	60	36.7

Two Australian studies (35 & 38) undertaken in Sydney provided valuations. Late displacement (travelling later than desired) was shown to have a higher cost (0.75) than early displacement (0.5) with an average value of 0.63.[41] Lower valuations would be required to derive the W+D function in Figure 15.[42] Guideline values of 0.33 for early and 0.5 for late displacement are therefore presented in Table 26 which compare with a range of 0.4 to 0.6 given by Wardman (2014) in his OECD review.

Figure 19: Sydney Rail Barrier exit profile



[41] The combined value is not the average of late and early displacement since passengers will travel earlier rather than later to minimise their overall displacement.

[42] Alternatively, a lower value of waiting time would be required.

Table 26: Value of travel time displacement

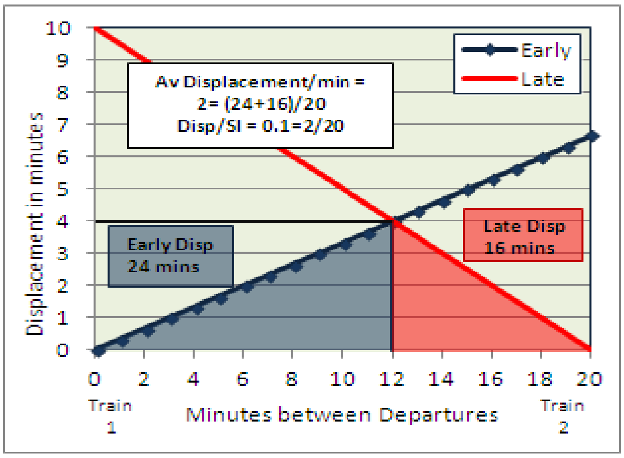
Estimate	Displacement per Minute			Timetable (SI)
	Early	Late	Average	Displacement^
Sydney Estimates	0.50	0.75	0.63	0.15
Recommended	0.33	0.50	0.42	0.10

+ Average of estimates of studies 35 and 38.

^ Timetable displacement is effectively the displacement values divided by 4.

The displacement value needs to be divided by 4 to measure the cost of service interval as Figure 20 shows. With values of 0.33 for early displacement and 0.5 for late displacement, and a uniform distribution of desired travel times, the watershed between two services 20 minutes apart would be 12 minutes (as opposed to 10 minutes) with more people travelling on the earlier service. Early displacement would total 24 minutes (0.33 x 12 x 12 ÷ 2) and late displacement would total 16 minutes (0.5 x 8 x 8 ÷2). Thus total displacement would be 40 minutes. Displacement would average 2 minutes and the cost would be 0.1 minutes per minute of SI.

Figure 20: Displacement SI multiplier



5. Transfer penalties and connection time

5.1 Introduction

Changing trains or buses imposes a 'transfer penalty' associated with the 'hassle' of breaking a journey (packing up belongings, disembarking then reboarding), the anxiety from potentially missed connections and extra 'information' costs.

Gross and net transfer penalties are distinguished. Gross transfer penalties include the connection time, which is expressed in equivalent IVT minutes. Net transfer penalties exclude connection time.

Twenty one studies providing 75 interchange penalties were reviewed. Nineteen studies were Australian (mainly NSW) and two were NZ. Most of the penalties were 'gross' and did not deduct the transfer connection time but twelve studies did provide a valuation of the connection time (usually waiting time) which enabled the two types of transfer to be placed on the same basis. The studies provided estimates for rail, bus, LRT and ferry involving 'same mode' transfers (e.g. rail-rail transfers) and 'different mode' transfers (e.g. rail-bus). Most different mode transfers involved bus.[43]

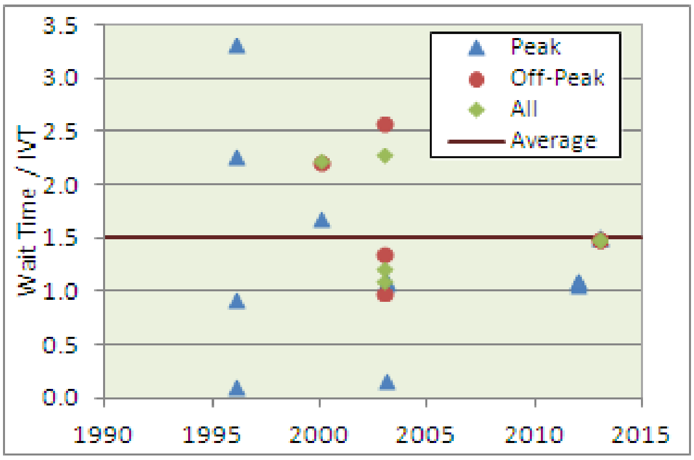
5.2 Valuation of transfer connection time

Thirteen studies provided 25 estimates of the value of time spent at the connection. In most studies, connection time was described as waiting time, but some studies also included walking time. Table 27 and Figure 21 present the estimates.

Table 27: Valuation of connection time in equivalent IVT

	Mean	Lower Quartile	Median	Upper Quartile	Obs
Weighted	1.50	1.1	1.2	2.2	25
Unweighted	1.48	1.1	1.5	1.95	25

Figure 21: Value of connection time in equivalent IVT



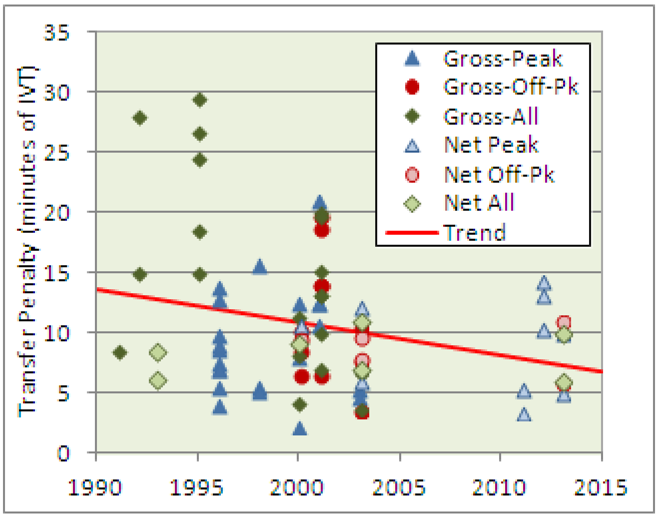
[43] An area of uncertainty with different mode transfers estimated by SP research is that respondents may value the travel time on the two modes differently. Studies 5 and 38 attempted to take account of this by applying travel time weights to the IVT on the different modes.

The average IVT valuation of connection time was 1.5. The valuation was therefore the same as walking time and slightly higher (0.1) higher than waiting time. Weighting the observations according to their relative accuracy had little effect and as can be seen from Figure 21 there was a wide spread in the estimates. The value compares with a value of 1.56 reported by Wardman (2001a) for wait time based on a meta analysis of UK studies.

5.3 Transfer penalty

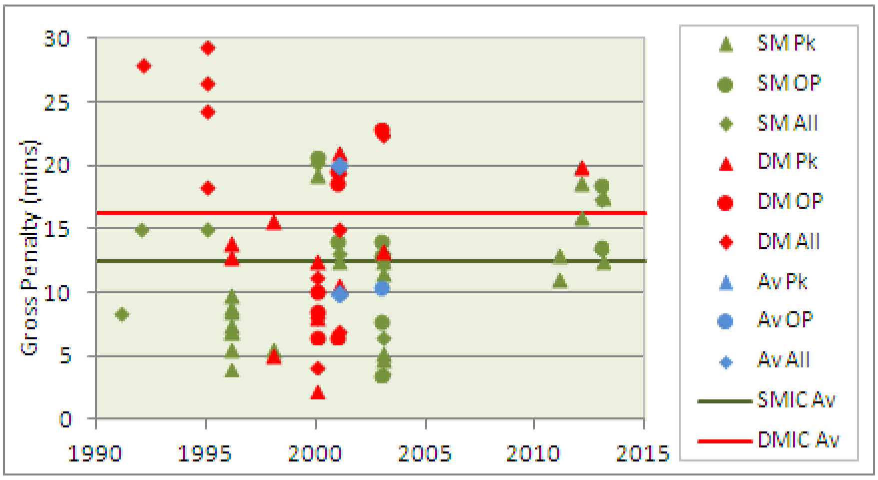
The 75 transfer penalty estimates are plotted by year of estimate in Figure 22. A downwards trend from 14 minutes in 1991 to 7 minutes in 2013 is evident but can be attributable to early estimates being 'gross' (including connection time) and later estimates being 'net'.

Figure 22: Gross and net transfer penalty estimates



After converting the net penalties into gross penalties by adding a connection time of 7.5 minutes (5 minutes of walk/wait multiplied by 1.5), the time trend became statistically insignificant. What emerged was for 'different mode' transfers (DM) to have a higher penalty than 'same mode' transfers (SM) as can be seen from Figure 23.

Figure 23: Gross transfer penalty estimates



Same mode penalties were valued at 12 minutes with an inter quartile range of 10 to 15 minutes. Different mode transfers were valued 4 minutes higher at 16 minutes and had an inter quartile range of 11 to 22 minutes). These are summarised in Table 28.

Table 28: Net transfer penalty and transfer waiting time

Estimates in equivalent IVT minutes

Type of Transfer	Mean	STE	Lower Quartile	Median	Upper Quartile	Obs^
Same Mode	12	0.6	10	13	15	44
Different Mode	16	1.3	11	16	22	29
All	14	0.7	10	13	19	75

^ 2 observations were not able to be categorised into same mode or different mode

observations weighted by relative t value

5.4 NSW 2013 interchange study

A detailed assessment of interchange penalties was undertaken by Douglas & Jones (2013). The study (included in the OECD Wardman (2014) review to illustrate the variation in transfer penalty) was undertaken as part of forecasting the demand for a proposed North West Rail Link that would involve a 'forced' cross-platform transfer at Chatswood from single deck to double deck trains. 939 Stated Preference interviews were undertaken (354 bus and 585 rail) on rail station platforms and CBD bus stops using computer tablets. Table 29 provides a summary.

Table 29: Transfer penalty by type of user

Estimates in equivalent IVT minutes

Interchange Type	Bus Respondents			Rail Respondents			ALL
	Short <30 mins	Medium >30 mins	All	Short <30 mins	Medium >30 mins	All	
Rail - Cross Platform	9	14	13	7	7	7	9
Rail - Change Platform	11	14	13	10	9	9	11
Bus-Rail Interchange	11	17	15	16	19	18	17
Bus-Bus Transfer	15	15	15	18	29	23	21

Source: Douglas & Jones (2013)

The estimated transfer penalties were greater for long trips (over 30 minutes) than short trips (less than 30 minutes). The penalties were lowest for cross platform rail transfers at 9 minutes. A transfer involving a change of rail platform was valued two minutes greater at 11 minutes. Transfers involving bus were greater averaging 17 minutes for a bus/rail transfer and 21 minutes for a bus/bus transfer. The penalties differed according to the current travel mode. Rail respondents had a lower penalty for rail transfers and a higher penalty for bus transfers than did bus respondents.

5.5 Gross and net transfer penalty estimates

Table 30 presents guideline gross and net transfer penalty estimates. The gross penalties are the same as in Table 28. Six minutes was deducted (4 minute connection time multiplied by a weighting of 1.5) to calculate net penalties of 6 minutes for a same mode transfer and 10 minutes for a different mode transfer.

Table 30: Gross and net transfer penalty estimates

Penalty	Type of Transfer		
	Same Mode	Different Mode	Rail Cross Plat
Gross Penalty^	12	16	10
Net Penalty^	6	10	4

^ calculated for a 4 minute connection at 1.5 x IVT

Based on the findings of the Douglas & Jones (2013) 2 minutes was deducted for cross-platform rail transfers (compared to a same mode transfer involving a change in platform via stairs or escalators).

By comparison, the OECD review by Wardman (2014) concurs with Litman (2014) in suggesting transfer penalties of between 5 and 15 minutes, Wardman added the qualification that *"this is expected to be at the lower end where good information and comfortable waiting conditions are provided and there is a minimum of insecurity, stress and effort".* Wardman considered there was evidence for a lower transfer penalty amongst commuters than for occasional users unfamiliar with transport arrangements.

6. Seat availability and crowding

6.1 Introduction

Crowding onboard trains and buses, especially in crush conditions makes travel less pleasant. In doing so and by making reading and the use of electronic devices harder, crowding increases the 'cost' of travel time.

Fourteen studies (10 Australian and 4 NZ) were reviewed that provided 30 values for rail, bus and LRT. Three of the Australian studies were undertaken specifically to value crowding. Two studies looked at on-train crowding: a Sydney study (28) of double deck trains and a 'capital cities' study (33) that looked at crowding for single deck trains. The other study looked at crowding at rail stations in Sydney (25). The remaining studies included crowding as one attribute in a wider study. One thing that all the studies had in common was the use of SP choice experiments to estimate the valuations.

6.2 Crowding values

Figure 24 plots the values of crowding by year of study. The estimates are classified into crowded seating, stand and crush stand values. Superimposed on the graph is the mean value of crowding calculated as an additional cost item to onboard travel time (IVT).[44]

Figure 24: Value of crowding relative to uncrowded seated IVT

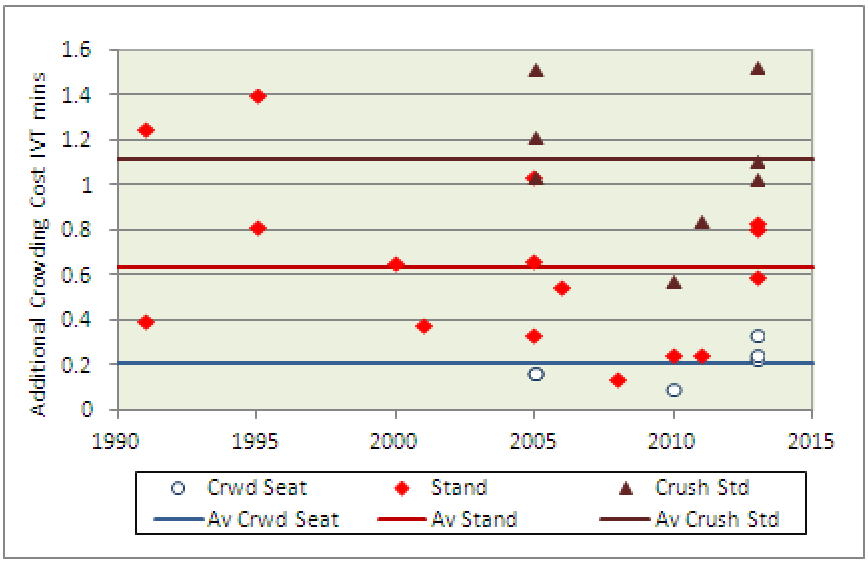


Table 31 presents the mean and quartile range. Crowded seating added 0.23 minutes per minute to the onboard travel time. Hence, 20 minutes of crowded seating adds 4.6 minutes

[44] Therefore, to express the values as an IVT multiplier, the values should be plus 1.

to the onboard time. Standing increased the cost to 0.65 minutes per minute of onboard time. Crush standing more than doubled the cost by adding 1.08 minutes per minute of onboard time.

Table 31: Cost of crowding

Cost (expressed in IVT minutes) is additional to the uncrowded seating time*

Statistic	Crowded Seat	Standing	Crush Standing
Mean	0.21	0.65	1.11
75% tile	0.25	0.83	1.29
Median	0.20	0.63	1.08
25% tile	0.17	0.37	0.98
Obs	6	16	8

* to calculate crowding IVT multipliers, 1 should be added.

Only one study (28) took account of the length of stand. The study found that standing for 20 minutes or more increased the 'per minute' cost by 40% compared with 'short stands' of up to 10 minutes. However, incorporating the length of stand into demand forecasts is not easy and requires information on the origin-destination of trips and a seat/stand algorithm.

The Sydney station crowding study (25) looked at the effect of crowding on waiting and walking time finding that high crowding doubled the cost of platform waiting time and increased the cost of walking by a multiplier of 1.6.

The OECD review by Wardman found a wide range in crowding values. For the UK, crowded seating added around 50% to the onboard time cost with standing adding between 0.62 and 1.93 minutes per minute depending on the load factor and the type of trip (leisure trips valuing crowding a fifth higher than commuters). Lower multipliers have been reported by Kroes (2013) for Paris with less difference between the seating (0.4) and standing (0.6) IVT multipliers.

6.3 Vehicle crowding cost functions

The easiest way of incorporating crowding into a demand forecast or evaluation is through crowding cost functions. These functions combine crowded seating and standing into a single IVT multiplier. The functions either reference the passenger load factor (passengers/seat capacity) or passenger density (passengers per square metre). Of the two measures, the load factor measure is the simplest since the base (uncrowded seating) can be set and maximum loads are usually known (200% being common) and sometimes 'legally imposed' in terms of a maximum number of standing passengers allowed on a bus. Passenger density on the other hand is less easy to define (because of seats, aisles and staircases) although the measure has found favour in the UK.

Five of the studies provided crowding cost functions (25 stations, 28, 33, 34 and 38). As an example, the functions developed for bus, rail and LRT in a 2013 Sydney study (38) are presented in Figure 25. The bus was a standard STA bus with 44 seats and space for 22 standing (150% max load factor). The LRT function was for a Variotram with 74 seats and

145 standing (300% max load factor) and the train was a Waratah double decker with 896 seats and capacity for 896 standing (200% max load factor).

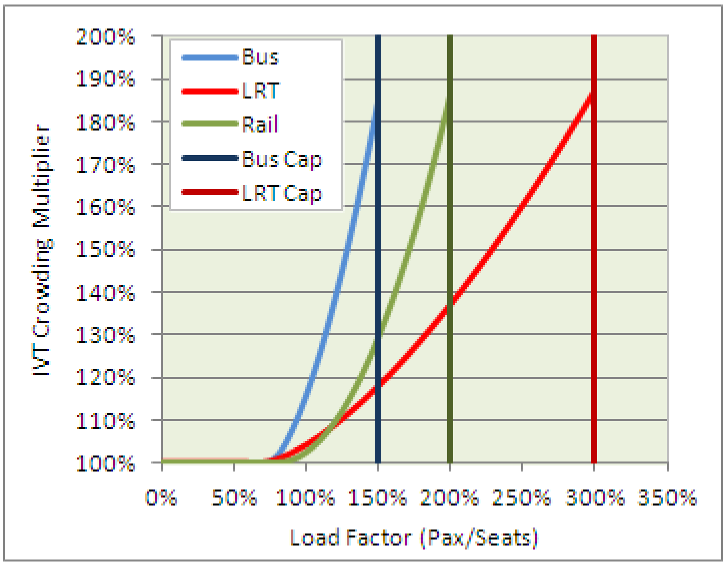
The crowding multiplier increases from a load factor of 80% and rises more steeply for bus and train than for LRT reflecting the greater space for standing on the LRT vehicle. The crowding IVT multiplier reaches a maximum at just under 1.9 at the maximum passenger load of each vehicle. The passenger cost of in situations where demand exceeds the maximum load could be assessed in terms of additional waiting time.

Figure 25: Crowding cost functions

Values estimated for standard Sydney buses, Sydney LRT Variotram and Waratah double deck train

Load Factor(1)	Bus	LRT	Rail
80%	102%	101%	100%
90%	108%	102%	101%
100%	116%	104%	102%
110%	126%	106%	105%
120%	138%	109%	109%
130%	152%	112%	115%
140%	168%	115%	121%
150%	184%	118%	129%
160%	na	121%	138%
170%	na	125%	148%
180%	na	129%	160%
190%	na	133%	172%
200%	na	137%	186%
220%	na	146%	na
240%	na	155%	na
260%	na	165%	na
280%	na	176%	na
300%	na	187%	na

(1) Passengers / Seats



6.4 Station crowding cost functions

Passenger crowding in stations particularly on platforms and in access-ways can make waiting and movement less pleasant. In Sydney, several evaluations have been undertaken at CBD stations to assess the cost of crowding and the benefit from increased capacity (e.g. Town Hall station 2007). For bigger investment proposals, computer simulation models are typically used.[45] One output of simulation models is the number of passenger minutes spent walking and waiting under different levels of crowding. Crowding IVT multipliers can then be applied to determine the cost of the crowding. There have been few studies to estimate the station crowding IVT multipliers. One Sydney study (24) was undertaken specifically to provide crowding multipliers for use in station evaluations. The multipliers, which were referenced against J. Fruin's station A - F classification,

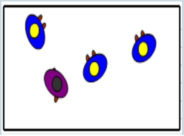
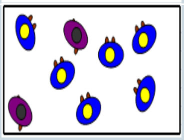
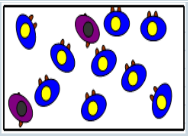
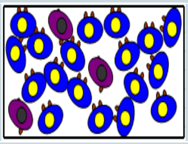
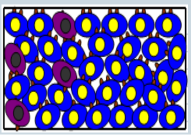
[45] Here the pioneering work of Gerry Weston at London Underground Operations Research in the development of station crowding models should be acknowledged. The 1987 Kings Cross tube station fire gave an impetus for the development of a general station pedestrian model in order to determine the evacuation time for each underground stations.

are given in Table 32.

Crowding reduces the walk speed and thereby increases the travel time. Hence, even without a crowding multiplier, station crowding will increase the generalised cost of travel at a rate of 1.5 IVT minutes per minute of walk time using the multiplier recommended in Section 2. It is only in environments E and F (when flow movement becomes heavily restricted) that walk times lengthen noticeably and the crowding cost multipliers become significant. For level E, the movement multiplier is 2.1 and the crowding multiplier is 1.1. Hence, the combined IVT multiplier would be 3.5 (1.5 x 2.1 x 1.1). For the most crowded environment, the multipliers rise exponentially to 3.61 and 2.77 giving a combined IVT multiplier of 15.

For waiting on platforms, there is no movement multiplier. However, the crowding multiplier is higher than for walking at 1.55 at level E and 3.66 at level F. These multipliers would be applied to the recommended wait time multiplier of 1.4 giving IVT multipliers of 2.12 and 5.1 respectively.

Table 32: Station crowding cost multipliers

Crowding Level	Description	Pax Flow Pax/min	Walk Speed M/sec	Max Density (PSM)	Movt Time Factor	Wait Crwd Mult	Walk Crwd Mult
A 	Movement restricted for majority, high restrictions for reverse flows. Sufficient waiting space.	1	1.32	0.31	1.00	1.00	1.00
B 	Minor movement conflicts. Sufficient waiting space.	23	1.26	0.43	1.05	1.00	1.00
C 	High probability of conflict for reverse flows and adjustment of speed. Sufficient waiting space.	33	1.14	0.71	1.16	1.00	1.00
D 	Movement restricted for majority, high restrictions for reverse flows. Sufficient waiting space.	49	1.12	1.08	1.18	1.02	1.00
E 	Major flow restrictions. Extreme difficulty for reverse flows. Some waiting discomfort.	66	0.63	2.13	2.10	1.55	1.10
F 	All movement extremely restricted. Complete flow breakdown. High discomfort for passengers.	82	0.37	3.60	3.61	3.66	2.77

Sources: J.J. Fruin Station classification; *"Pedestrian Planning & Design"* (1971); Crowding multipliers from *"Value & Demand Effect of Rail Service Attributes"*, Report to RailCorp by Douglas Economics, July 2008.

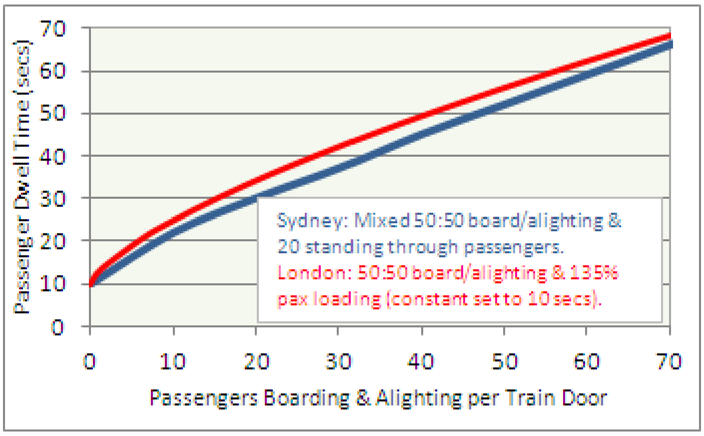
6.5 Train and station crowding and train dwell times

Crowding onboard vehicles and also on platforms can lengthen board and alight times thereby constraining the overall passenger carrying capacity of a service. In most situations, the impact of crowding will be small enough to be ignored but on crowded 'through CBD" lines such as the North

Shore/Main West rail line between Redfern and Wynyard in Sydney, where peak services are at, or approaching, maximum physical capacity, impacts can be significant. Indeed, catering for such passenger growth can be the trigger for new CBD rail line proposals costing billions of dollars.

To illustrate the effect of passenger numbers, Figure 26 shows how passenger dwell time increases with the number of passengers boarding and alight per train door. Two curves are plotted, one using a function developed by London Underground (Weston 1989) and one developed using Sydney statistics (Douglas Economics 2012). As can be seen, the functions are quite similar with dwell times increasing from 10 seconds to just over a minute with 70 passengers boarding/alighting per door. As a rule of thumb, one second per passenger per door can be used.

Figure 26: Passenger load and passenger dwell time



7. Timetable reliability

7.1 Importance of reliability

Although 'reliability' could apply to a range of service delivery aspects such as getting a seat, whether the vehicle is air conditioned or the accuracy of travel information, it is now synonymous with how well services run to a timetable.

Surveys of customer opinion have consistently shown that timetable reliability is one of the most important determinants of overall service quality from a passenger's perspective. A 2009 survey of Sydney bus users by the Independent Transport Safety and Reliability Regulator (ITSRR) found 88% of respondents considered that 'buses keeping to timetable' was important or very important (ITSRR 2009). In the UK, a national survey of rail passengers by MVA ranked service punctuality first out of 30 attributes in importance in 2005 and third in 2006 (MVA 2007). For Sydney, a 2006 survey found reliability to be the dominant factor in explaining rail passengers' overall rating of service accounting for 25% of the overall rating (Douglas & Karpouzis 2006). Finally, Wardman (2014) placed reliability in the 'most important' category of convenience related attributes.

7.2 Reliability measures

Reliability is generally measured in terms of the reliability in the departure times at bus stops or the reliability in the travel time spent on the bus.[46] Unlike other travel time attributes, reliability is less easy to measure and predict. The following five measures have been the most frequently used:

- Average Mean Lateness (AML)
- Schedule Delay Early (SDE) and Schedule Delay Late (SDL)
- Standard Deviation in travel time (SD) often expressed as ratio of the mean travel time and called the Reliability Ratio (RR)
- Buffer Index
- Customer Journey Time Delay.

Average Mean Lateness (AML) has been the most used in Australia and NZ for performance statistics and in SP valuation surveys. Likewise, In the OECD review, Wardman (2014) notes that AML has been widely used in the UK underpinning the regulatory mechanism, driving fines and compensation payments on operator and infrastructure providers. For buses, the measure tends to be calculated in terms of the arrival time at bus stops and is viewed by passengers as excess waiting time. For trains, reliability is usually calculated at key arrival stations and is reported as the percentage of trains arriving more than X minutes late. For the rail passenger the focus is therefore more towards delays on the train than at the stop. AML is simple to calculate and to

[46] Kittelson & Associates (2003), Mazloumi et al. (2008), Trompet et al. (2011) provide reviews of alternative reliability measures.

understand: if 10% of trains are 10 minutes late, AML is 1 minute. Quite often however, the degree of lateness is not measured in operator statistics with the mirror image reported: 90% of trains are on time (with on time being within 5 minutes of the scheduled arrival time).

Schedule Delay Early (SDE) and Schedule Delay Late (SDL) are measured relative to a preferred arrival time. In this regard they are like the displacement (Section 4). A related measure is the buffer index which defines the additional travel time a passenger should allow in order to arrive at their destination at a given time.

The standard deviation is the statistical measure of dispersion in arrival times around the mean arrival time. To standardise the measure, the SD is often divided by the mean travel time to compute a reliability ratio (RR). The RR measure is used in the UK and in Europe.

The 'buffer index' is the extra time travellers build into their journey time to take into account of expected travel time variability. The measure requires knowledge of the distribution of travel times and is usually calculated by subtracting the median time from the 95 percentile time. The resultant buffer time is then multiplied by the Reliability Ratio (usually 1).[47]

Customer journey time delay measures the difference between the customers expected and actual travel time from the start to the finish of a trip.[48] Waiting time as well as the in-vehicle time is included so that the measure represents the travel time reliability of the whole trip. To do this, knowledge of a customer's origin and destination stops/stations are required. Moreover, departure and arrival times for the origin and destination bus stops need to be combined, both scheduled and actual. Calculation of the measure is therefore far more complex than the 'single index' measures.

Wardman (2014) in an OECD review considered that *"official values for public transport are either based around mean lateness (AML) or the RR"*.

7.3 Valuation of average mean lateness

Ten studies were reviewed (Australian and NZ studies). All 10 studies were undertaken before 2009 and are therefore somewhat dated. The most recent study was a 2008 study by Vincent which had the specific aim of valuing reliability. Earlier studies included reliability as one attribute in a more general survey.

Most of the studies predated the introduction of real time information (RTI) electronic displays and the provision of timetable and service disruption messages via mobile phones and computers. It is likely that these sources of information would have reduced the uncertainty and anxiety of service unreliability and with it the IVT multiplier for reliability.[49]

All 10 studies measured reliability using Average Mean Lateness (AML). Altogether 15 estimates were collated which are presented in Figure 27 and Table 33. Three estimates measured AML at

---

[47] See for example Wang (2014) *"Economic Evaluation of Travel Time Reliability in Road Project Planning: a Practitioner's* Perspective", Paper given at the 26th ARRB Conference – Travel Time Reliability, Sydney, New South Wales 2014.

[48] Currie et al. (2013) evaluated customer delay against nine other measures for measuring bus service reliability. Customer delay was ranked equal first with excess waiting time.

[49] A 'Metro' study by Hensher undertaken in 2011 did include 'expected' travel time as a variable.

the departure station (or stop) and three at the arrival station but nine were nonspecific.

Of the two measures, departure AML with an IVT multiplier of 5.9 was twice as costly as arrival AML at 2.8; the higher valuation probably reflecting the cost of waiting at stops versus delays onboard vehicles. The nine non-specific reliability estimates had an IVT multiplier of 4.0.

The overall average AML multiplier was 4.1 which is probably the most useful measure for CBA purposes. The values are comparable to the ‘official values’ reported in an OECD review by Wardman (2014) which ranged from 1.5 to 6.

Figure 27: Valuation of average mean lateness

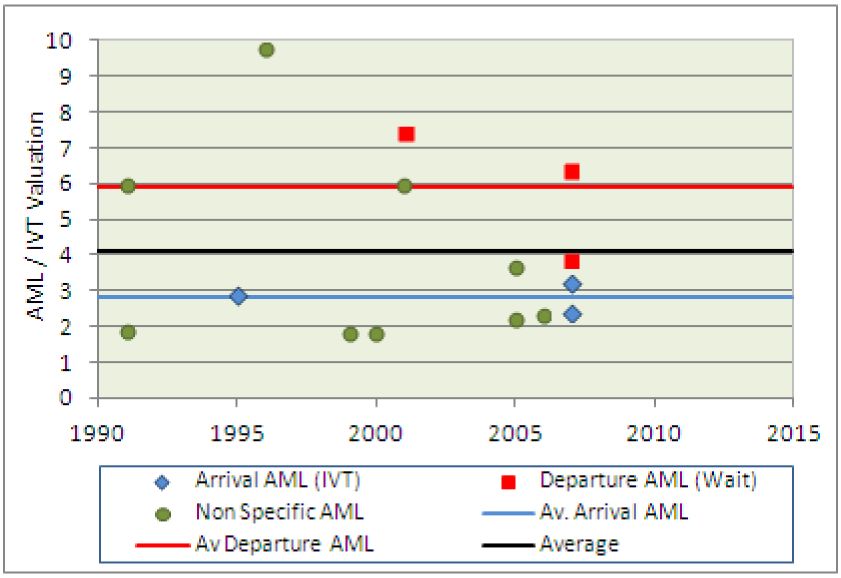


Table 33: Valuation of average mean lateness

AML Estimate	Mean	Median	Interquartile Range*	Obs
Departure (Wait)	5.9	6.4	3.9 - 7.4	3
Arrival (On-Vehicle)	2.8	2.9	2.4 - 3.2	3
Non specific	4.0	2.3	1.9 - 6.0	9
Average	4.1	3.2	2.2 - 6.0	15

* 25 percentile - 75 percentile; unweighted obs. (weighted mean = 4.4)

7.4 Other values of reliability

The Vincent study (32) attempted to produce valuations using measures other than AML but the results were unsuccessful. Therefore in Table 34 overseas estimates for SDE, SDL and the RR are tabulated. SDL at 1.8 was valued just under half AML. SDE was valued around half SDL with RR valued between SDE and SDL.[50] Assuming these ratios applied to Australia/NZ, the value of SDE would be 1, SDL 2.3 and RR 1.5.

[50] Bates (2001) has shown that SDE, SDL and the RR measure are mathematically related through the equation:

$$RR = SDE \ln\left(1 + \frac{SDL}{SDE}\right)$$

Table 34: Values for other reliability measures

Measure	Wardman			Teng	Carrion & Levinson			All	Australia&NZ
	Mean	Range		Mean	Mean	Range		Average	Estimate+
SDE	0.86	0.52	1.2	0.75	-	-	-	0.81	*1.0*
SDL	1.94	nk	nk	1.65	-	-	-	1.80	*2.3*
RR	1.02	0.20	1.2	1.33	1.2	0.1	3.3	1.18	*1.5*
AML^	3.24	1.5	6	-	-	-	-	3.24	4.1
Studies	nk	nk	nk	16	17			nk	12
Obs	SDE 48, SDL 54, AML 27 & RR 31			74	68			nk	15

^ range (observations combined with SDL by Wardman). nk not known

+ based on average value multiplied by the ratio of AML Australia&NZ (3.9) / Wardman estimate3.24)
Sources: Wardman (2013), Teng (2008), Carrion & Levinson
(2013)

7.5 Valuing reliability benefits in practice

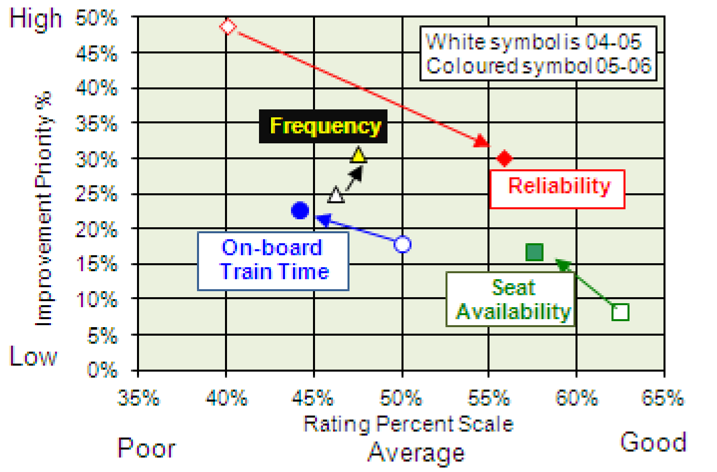
Applying a valuation is the easiest part of forecasting the effects of reliability. The more difficult part is forecasting the change in reliability itself. For larger projects, computer simulation is often used. For rail, there are ‘off-the shelf’ packages available to model timetable performance. Likewise, road traffic simulation packages can be used to model bus reliability.

Two examples of computer simulations are Sydney CBD & South East Light Rail and the Bus and Train Tunnel in Brisbane. For the Sydney Light Rail project, forecast reliability benefits amounted to 13% of time savings plus amenity benefits. For the Brisbane bus and rail tunnel, reliability benefits represented 30% of time saving benefits.

What will largely determine the size of benefit is how much unreliability can be countenanced in any system. A reasonable starting position is to assume that unreliability will not get materially worse than in the present system and that timetables would be ‘slowed’ to accommodate extra services or that passengers would be ‘displaced’ out of the peak hour. The passenger disbenefit would then be longer onboard travel times and/or travel time displacement but no extra unreliability.

As an example, in 2004/05, Sydney rail users rated reliability particularly poorly scoring it 40% (on a 0% very poor to 100% very good scale), much lower than for frequency, in-vehicle time and seat availability (Douglas Economics 2006). In terms of importance, reliability accounted for one half of passengers’ priority for improvement with onboard time, seat availability and frequency improvements accounting for the other half. In response to adverse public and media reaction, RailCorp changed the timetable by slowing or removing some services. In response, the reliability rating improved but on the downside, the rating of onboard time and seat availability declined. The net effect, as can be seen from Figure 28, was a more balanced passenger assessment and it is this ‘balance’ that should be the aim in developing future timetables for forecasting purposes.

Figure 28: Sydney Rail – effect of timetable change on passenger ratings



Service Attribute	Rate % 04-05	Rate % 05-06	Improvement Priority % 04-05	Improvement Priority % 05-06
● Onboard Time	50%	44%	18%	23%
△ Service Frequency	46%	48%	25%	31%
◆ Reliability	40%	56%	49%	30%
■ Seat Availability	63%	58%	8%	17%

Source: RailCorp Surveys, Douglas Economics Analysis QSF06_Analysis_4.xls!Imp2

For proposals that are expected to improve timetable reliability on current levels, one practical approach is to 'factor up' travel time savings. In an evaluation of bus lane proposals for Wellington, Wallis & Associates added a quarter of the travel time savings to take account of expected reliability gains (Wallis 2008) based on 'before and after' studies of London bus lanes,

7.6 Wider Impact of Unreliability

One issue that can be overlooked is the impact on others of bus and train service unreliability. Meeters and greeters for instance will usually have to wait longer at the train station when trains are delayed. Meetings may have to be re-arranged and dinners re-heated. These costs impact on 'non-users' and unless the public transport user took these wider costs into account when surveyed, the total cost of unreliability will be underestimated.

8. Vehicle quality

8.1 Introduction

Valuing attributes that have qualitative aspects is rubbery 'science' since what one person likes another may dislike. The number, width and leg-room of seats can be quantified but assessing their colour and styling is essentially qualitative.

The approach taken here is to base the values of bus, train and ferry vehicle quality and also bus stops, train stations and ferry wharfs (see section 9) on passenger ratings.

Passenger ratings average passenger opinion and provide a continuous measure but one that is limited to the range of the rating scale. The ratings presented here range from 0% for 'very poor' to 100% for 'very good'.

Unlike unbounded inflation and GPP indices, the finite range of ratings places a limit on their application. To illustrate the point, consider a Model T Ford. When the Model T rolled off the production line at the beginning of the 20th century, it would have scored a high rating amongst its buyers. However a century on, given the enormous improvements in vehicle technology, the Model T would most likely obtain a poor rating other than for its vintage appeal.[51]

Within a shorter time period, advances in bus, train and ferry design will still occur that will tend to reduce a vehicle's rating (assuming people rate a vehicle relative to other vehicles). It is also worth noting here that trains and ferries are often assumed to have an economic life of 30 years.

Rating surveys have been undertaken over 10 to 20 years in NZ and NSW using similar questionnaires which has enabled longer term trends in passenger rating to be established for trains and stations.

In addition, surveys undertaken at a single point in time have covered different buses, trains and ferries within a fleet which allows the effect of vehicle age, vehicle design and features to be assessed cross-sectionally.

The rating approach presented here has been developed to evaluate different vehicle attributes such as lighting and outside vehicle appearance as well as the overall vehicle. The approach does not require any 'capping' or 'scaling down' of individual attributes to calculate 'package' values. This is because the values were estimated using a top-down approach. The value of the overall vehicle rating was valued and then disaggregated amongst individual vehicle attributes. The method has been extended to allow for 'halo effects' whereby changing one vehicle attribute e.g. lighting can affect the rating of other attributes e.g. ease of boarding and alighting.

The values can be used to assess the provision of attributes as well as the 'quality' of provision. Thus the effect of providing air conditioning on a bus can be valued. Provision would reflect the average passenger rating of vehicles with air conditioning versus the rating of vehicle without air conditioning.

The method can also be used to assess the quality rating of an attribute (or package of attributes)

---

[51] As will be shown in section 8.4, a W class tram built in 1952 and operating in Melbourne city centre obtained a high passenger rating when surveyed in 2014. However had the whole fleet been retained, it is unlikely the same high rating would have been achieved.

as viewed by passengers. Thus the cleanliness of trains and buses, the friendliness and helpfulness of the staff and the smoothness and quietness of the ride can be assessed. Quality is measured via the rating scale. Thus improving vehicle cleanliness from an average (50%) rating to a good (75%) rating could be assessed.

The values are based on three studies: NZ, NSW and Victoria. A 2012-13 New Zealand study surveyed bus and train services in Auckland, Christchurch and Wellington (and Wellington rail stations a decade previously using a similar questionnaire). A 2013-14 NSW study surveyed bus, light rail, rail[52] and ferry services[53] in Sydney, Newcastle and Wollongong plus rating surveys of trains and stations conducted from 2002. A Melbourne study surveyed bus, tram and rail services in 2014.

These three studies are supplemented by a literature review of Australasian and overseas values undertaken as part of the 2012-13 NZ study[54] and by Currie and De Gruyter (2019).

The rating approach was developed by Douglas & Karpouzis in a 2006 study of Sydney rail. The resultant values were used in economic evaluations of train and station improvements.

The NZ study developed the Sydney approach. 12,500 Auckland, Christchurch and Wellington bus and train passengers were surveyed in 2012-13. The survey involved Rating and a Stated Preference self-completion questionnaires handed out on trains and buses. The rating questionnaire measured the quality of the buses and trains and bus stops and train stations. By recording the details of the vehicle and stations, the passenger ratings were able to be explained in terms of 'objective' data such as vehicle and station age, vehicle and stop/station type and facilities. The Stated Preference questionnaire determined the value passengers placed on overall vehicle and stop/station quality relative to service frequency, in-vehicle time and fare.

The same questionnaires were used in Sydney, Newcastle and Wollongong in 2013-16 to estimate service quality parameters for bus, train, Light Rail and ferry and again in Melbourne in 2014 to estimate values for bus, tram and train services for Public Transport Victoria.

8.2 Valuing Changes in Overall Vehicle Quality

The rating based approach to value changes in vehicle quality has three steps as per Figure 29.

Step 1 determines the maximum value that passengers place on overall vehicle quality i.e. from 0% (very poor) to 100% (very good) with value measured in equivalent in-vehicle travel time minutes.

---

[52] The values for rail are based on surveys of passengers using metropolitan and outer metropolitan but not longer distance regional rail services (e.g. CountryLink). The NZ study (37) surveyed the Wairarapa rail line which caters for trips of up to 1½ hours. The Melbourne study (39) surveyed metropolitan rail services.

[53] Values for ferry are from a 2014 TfNSW study that surveyed Sydney Harbour and Parramatta river services, the Newcastle ferry and privately operated Manly fast ferries.

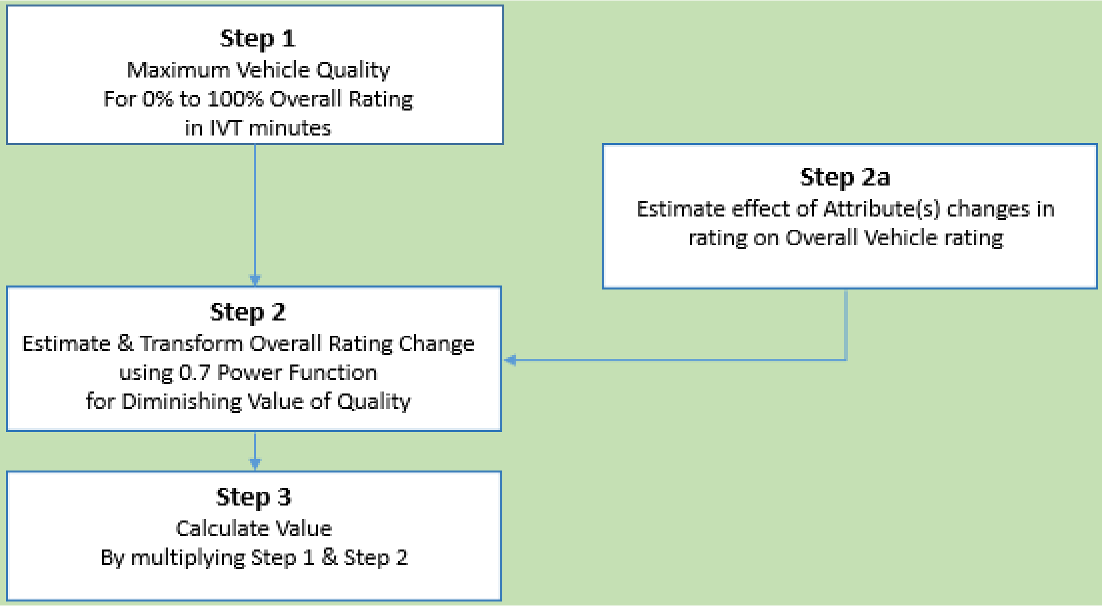
[54] The literature review draws from a study undertaken by Douglas Economics for NZTA *'Pricing Strategies for Public Transport'* in 2012/13. Thirteen studies were reviewed of which five were Australian, two were NZ and seven were 'international' (5 UK, 1 USA and 1 Norway). Stated Preference and Priority Evaluator techniques (a shopping list of improvements) were used to estimate values.

Step 2 calculates the proportion of the maximum value that a particular change in rating represents allowing for a diminishing valuation of quality as ratings increase.

Step 3 applies the proportionate change in rating (step 2) to the maximum value of quality (step 1).

Step 2a: When improvements or changes to individual vehicle attributes or a combination of attributes needs to be evaluated a subsidiary step is needed. Step 2a applies a factor that measures the relative importance of the attribute in determining the overall vehicle rating allowing for direct and indirect or 'halo' effects. Section 8.3 describes step 2a.

Figure 29: Three Step Valuation Approach



A set of 'benchmark' ratings for buses, trains, trams, light rail and ferries based on the NZ, NSW and Victoria surveys is provided in section 8.4. These ratings may help assess the likely change in rating a particular proposal might have.

As with vehicle quality if individual attributes or combination of attributes need to be evaluated rather than the overall quality of a stop or station, a subsidiary step **(2a)** is needed A set of 'benchmark' ratings for bus and tram stops, train and Light Rail stations and ferry wharfs are provided based on the response to rating surveys undertaken in NZ, NSW and Victoria. These estimates help assess the likely change in rating a particular proposal might have.

Step 1: Determining the Maximum Quality in Equivalent In-vehicle time minutes

Changes in vehicle quality are value using the same numeraire as access/egress, frequency and reliability i.e. by measuring the change in equivalent in-vehicle time minutes.

In the surveys, vehicle quality was measured on a percentage scale with a very poor passenger rating scoring 0% and a very good rating scoring 100%. Intermediate points were poor (25%), average (50%) and good (75%).[55]

The Maximum Vehicle Quality (MVQ) refers to the maximum rating difference of 100% i.e. from very poor 0% to very good 100% valued in-vehicle time (IVT) minutes. Based on the NZ, NSW and Melbourne surveys, MVQ increased at half the rate of the onboard trip time from a base of 4 minutes:

MVQ = 4 + 0.5 x IVT .....(8.1)

The function allows for passengers making longer trips to value the quality of ride, seating, lighting etc more than passengers making short trips. The 'constant' of 4 minutes accounts for the outside vehicle appearance and boarding and alight aspects which were found to be independent of trip length.

Table 35 presents MVQ functions for rail, bus, Light Rail (LRT) / tram and ferry.

The average IVT was 27 minutes. With the valuation function, the maximum value of vehicle quality (MVQ) was 17.5 minutes (4 minutes + 0.5 x 27 minutes).

Table 35: Maximum Vehicle Quality

Value of a 100% rating difference (Very Poor to Very Good) in Equivalent IVT minutes

Mode	Max Veh Quality (MVQ) mins		MVQ/Trip	Av Trip	Evidence
	Constant	Per Minute	IVT mins	IVT mins	
Rail	4.4	0.55	23.7	35	NZ, NSW, VIC
Tram/LRT	3.2	0.41	11.4	20	NSW, VIC
Bus	3.2	0.4	13.2	25	NZ, NSW, VIC
Ferry	1.3	0.43	11.6	24	NSW
Public Transport	4	0.5	17.5	27	ALL

The value of vehicle quality was highest for rail (23.7 minutes for the average trip of 35 minutes). The MVQ for tram/LRT and bus was roughly half that of rail reflecting shorter trips (20-25 minutes) and smaller MVQ parameters. Ferry quality was valued similar to bus and tram/LRT but with a lower constant and slightly higher travel time value.

Step 2: Determine the Proportion of the Maximum Value for a particular proposal

Step 2 calculates the proportion of maximum value of quality (MVQ) that applies to a particular change in quality.

It is highly unlikely that the maximum value of quality (100%) will apply since not everyone would rate a vehicle at 0% (very poor) before an improvement and 100% (very good) after it. Thus, the change in rating will be less than MVQ.

[55] The percentage scale were derived from a 1-9 scale used on the rating questionnaires and a 1-5 scale used on the Stated Preference questionnaire. The 1-9 rating scale was converted to a percentage by subtracting 1, dividing by 8 and expressing the resultant ratio as a percentage. Likewise the 1-5 scale was converted by subtracting 1 and dividing by 4 and expressing the ratio as a percentage.

Based on the NZ, NSW and Victoria studies, a difference of 40% to 80% is considered a reasonable range for a major improvement in vehicle quality (see section 8.4).[56]

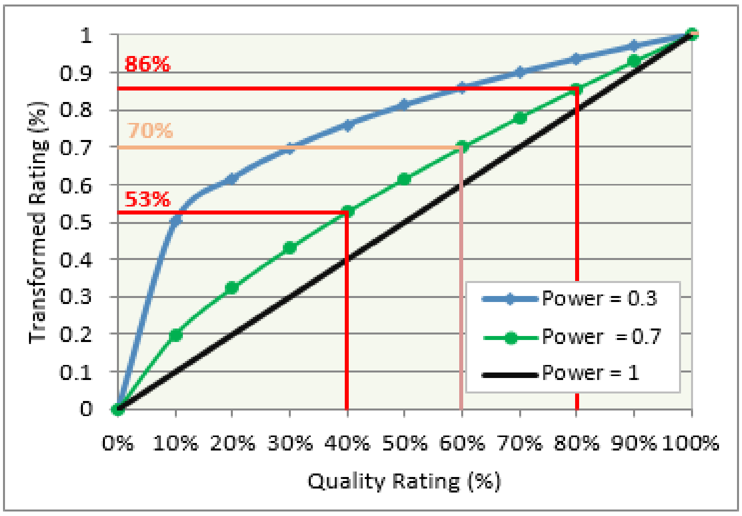
However, it would not be correct to take 40% (80% - 40%) of the MVQ since the surveys found Willingness to Pay (measured in IVT, fare or frequency) for improvements declined as base quality increased. Improvements in rating from very poor (0%) to poor (25%) were valued more than improvements from poor (25%) to average (50%). Likewise, improvements from average (50%) to good (75%) were valued more than improvements from good (75%) to very good (100%). So despite the difference in rating being the same (25% points), WTP declined as base rating increased.

To take account of the diminishing valuation, Step 2 transforms the rating scale. The transformation is based on the evidence of the NZ, NSW and Victoria studies which fitted difference functions to the data. A power function that raises the rating (R) by a power of 0.7 fitted the response data and transforms the rating (Rt) as shown in equation 8.2

$Rt = R^{0.7}$ .....(8.2)

Applying the transformation function has the effect of increasing the rating except at the end points of the scale (0% and 100%) where the ratings are unaffected by transformation. Figure 30 shows the effect of adopting alternative values for the power function. As can be seen, the closer the power value is to 1, the straighter the line between 0% and 100% and the less the effect of transformation.[57]

Figure 30: Transformed Quality Rating Scale



The maximum value of quality (MVQ) i.e. from 0% to 100% remains 100%. Transformation only affects ratings between 0% and 100%. Table 36 provides a transformation of the rating scale with a power value of 0.7.

[56] The range in the overall vehicle rating over the three surveys for all four public transport modes was a little wider from 37% to 85%.

[57] A power value greater than 1 would produce a U shaped curve below the diagonal whereby a change from good (75%) to very good (100%) was valued more than a change from very poor (0%) to poor (25%).

Table 36: Transformed Quality Rating Scale

Quality	Very Poor		Poor			Average			Good			Very Good	
Rating %	0%	10%	20%	25%	30%	40%	50%	60%	70%	75%	80%	90%	100%
Transformed %^	0%	20%	32.4%	37.9%	43.1%	52.7%	61.6%	69.9%	77.9%	81.8%	85.5%	92.9%	100%

^ Rating raised to the power of 0.7

As an example, consider an improvement that improves the overall vehicle rating from 40% to 80%. The base vehicle rating (R1) of 40% would transform to a valuation rating of 52.7% (Rt1 = $0.4^{0.7}$). After the improvement, the 80% vehicle rating (R2) transforms to 85.5% (Rt2 = $0.8^{0.7}$). The change in transformed rating is 32.8% (ΔRt = Rt2 - Rt1 = 85.5% - 52.7%) which is close to a third of the valuation rather than the actual change of 40% points (ΔR = R2 - R1 = 80% - 40%).

Step 3: Multiply the maximum value of vehicle quality with the transformed change in rating

The maximum value of vehicle quality (MVQ) calculated in Step 1 is multiplied by the change in the transformed rating (ΔRt) in Step 2 to value of the improvement in equivalent in-vehicle time minutes.

If a new vehicle was introduced on a service with an average passenger trip length of 27 minutes and increased passenger ratings from 40% to 80%, the improvement would be worth 5.7 minutes in equivalent in-vehicle time (32.7% of 17.5 minutes).

$$\Delta IVT = MVQ \times \Delta Rt = 17.5 \times 0.327 = 5.7 \text{ IVT minutes} \quad \ldots..(8.3)$$

Table 37 presents the values by mode for a 40% to 80% rating improvement taking account the average trip lengths. As can be seen, the values are a third of the maximum value.

Table 37: Value of Vehicle Quality for a 40% to 80% Rating Difference in equivalent IVT minutes

Mode	MVQ	40% - 80% Difference	Av Trip Length	NZ Review	De Gruyter Review
Rail	23.7	7.8	35	3.6	8.5
LRT/Tram	11.4	3.8	20	-	-
Bus	13.2	4.3	25	4.4	5.3
Ferry	11.6	3.8	24	1.2*	-
Public Transport	17.5	5.8	27	3.8	-

* estimated by Booz (2000) for Sydney Ferries

On the right hand side of the table are values for bus and rail determined by a literature review undertaken as part of the NZ study and a 2018 international review by De Gruyter (see section 8.9). The literature review estimates are both medians. The NZ review was for 7 rail and 9 bus studies that used Stated Preference type questions to value differences such as ‘old versus new’, ‘standard versus new’ and ‘worst versus best’. The bus value of 4.3 minutes is nearly identical to the median value of 4.4 minutes reported by the NZ literature review. It is a minute less than the median value of 5.33 minutes calculated from the De Gruyter review figures.

The rail value of 7.8 minutes is twice as high as the NZ literature figure of 3.6 minutes but is a little lower than the 8.5 minutes calculated from the De Gruyter review.

For ferry value of 3.8 minutes compares with a value of 1.1 minutes estimated by Booz Allen Hamilton in 2000 in a study of Sydney Ferries for a raft of ferry improvements (valued from the current standard) for a 25-minute trip.

8.3 Valuing Changes in the Quality of Vehicle Attributes

There will be instances where changes to individual vehicle attributes or combinations of attributes need to be evaluated rather than changes to overall vehicle quality such as a change to vehicle cleanliness or to driver/staff friendliness. To evaluate a change in one attribute or a combination of attributes, an additional step is needed. This step is referred to as step 2A.

Step 2A takes account the relative importance of different vehicle attributes. Importance measures the extent to which the overall vehicle rating is likely to change in response to a change in attribute rating. Importance was established by regression analysis of the NZ, NSW and Victoria ratings data. Regression explained the variation in the overall vehicle rating in terms of the individual attribute ratings.

Table 38 presents the relative importance of the vehicle attributes surveyed in the NZ, NSW and Victoria surveys. The comparison is complicated by differences in the attribute lists included on the questionnaires. As an example, the questionnaire used in surveys of Sydney train passengers in 2004 and 2012 included 'train layout' and 'personal security' but these attributes were not included on the 2014 Sydney questionnaire or the NZ and Victoria surveys.

Table 38: Relative Importance of Individual Vehicle Attributes

	MEL	NZ	SYD	NSW by Mode			
Vehicle Attribute (1)	B,T,R	B,R	B,R,L	Bus	LRT	Rail	Ferry
Oustide Vehicle Appearance	14%	13%	13%	12%	14%	7%	14%
Ease of Getting On-Off	5%	7%	8%	9%	11%	11%	21%
Seat Availability & Comfort	9%	12%	10%	9%	9%	10%	12%
Space for Bags	6%	4%	1%	2%	4%	1%	5%
Smooth & Quietness	3%	14%	11%	10%	12%	8%	10%
Heating & Air Conditioning	10%	7%	11%	8%	9%	6%	6%
Lighting	12%	2%	6%	7%	7%	9%	5%
Cleanliness & Graffiti	14%	8%	10%	16%	5%	10%	12%
On-board Information	9%	6%	6%	3%	3%	5%	4%
WIFI- Internet Connectivity	4%	1%	0%	0%	0%	4%	2%
Driver / Staff	2%	14%	14%	16%	14%	6%	na
Environment Impact	10%	10%	10%	8%	12%	5%	4%
Toilet Availability & Cleanliness	na	2%	na	na	na	2%	na
Onboard Food/Drink	na	na	na	na	na	na	5%
Train Layout	na	na	na	na	na	11%	na
Personal Security	na	na	na	na	na	5%	na
Onboard Ticket Purchase	2%	na	na	na	na	na	na
Total	100%	100%	100%	100%	100%	100%	100%

(1) Abbreviated descriptions – longer descriptions were on the questionnaires

The Victoria questionnaire included onboard ticket purchase but the NZ and NSW questionnaires did not. Toilet availability and cleanliness was only included on longer distance rail services in NZ and NSW.

Five attributes explained most of the variation in the overall rating: outside vehicle appearance, ease of getting on and off, seat availability and comfort, smoothness and quietness, and cleanliness and graffiti; each explained 10% to 15% of overall importance.

Valuing the direct effect of a change in the rating of an individual attribute or combination of attributes is straightforward. Step 2A requires that the change in attribute rating (ΔAi) is multiplied by its direct importance (Di) to determine the change in overall rating (ΔR) which then needs to be added to the base overall rating (R1) to get the new overall rating (R2).

$R2 = \Delta R + R1 = (\Delta Ai \,.\, Di) + R1$ …..(8.5)

The base and overall vehicle ratings then need to be transformed using the power function (equation 8.1)

As an example, consider a proposal to refurbish the seats of a train. Refurbishment is expected to improve the seat rating by 20% for a train with an overall vehicle rating of 60%. From Table 38, the importance of train seat availability and comfort is 10%. Multiplying 20% by 10% gives a predicted increase in the overall train rating of 2%. Applying the power transformation to the base (60%) and new (62%) overall ratings gives a transformed difference of 1.7%. For an average 35 minute rail trip, the improvement would be worth 1.7% of 23.7 minutes (Table 37) which is 0.4 minutes.

Analysis of the Sydney ratings found vehicle attribute ratings to be correlated. For rail, the strongest correlation was between 'space for personal belongings' and 'seat availability and comfort' (r=0.7). Second strongest was 'smoothness and quietness' and 'seat availability / comfort' (r = 0.68) and third was between 'air conditioning / heating' and 'lighting' (r = 0.66).

The correlations suggest that improving one attribute's rating would tend to increase the ratings of other attributes and, by so doing, increase the overall vehicle rating. This effect is referred to as the 'halo effect' with the total effect comprising the direct plus the halo effect.[58]

Table 39 sets out the estimated direct and halo effects for Sydney buses, trains and ferries.[59]

Unlike the direct effect, the sum of the halo effects does not need to sum to 100%. In Table 39 the sum ranges from 88% for ferry to 109% for rail.

Including the halo effect is straightforward for a single attribute improvement involving the multiplication of the change in attribute rating (ΔAi) by the sum of the direct importance (Di) plus the halo importance (Hi). The result is the predicted change in overall rating (ΔR) which can added to the base overall rating (R1) to get the new overall rating (R2). Equation 8.6 sets out the calculation.

$R2 = \Delta R + R1 = (\Delta Ai \,.\, (Di+Hi)) + R1$ …..(8.6)

The base and new vehicle ratings then need to be transformed using the power function (equation 8.1)

---

[58] The halo effect was named by psychologist Edward Thorndike in reference to a person being perceived as having a halo. Thorndike, EL (1920), "A constant error in psychological ratings", Journal of Applied Psychology 4 (1): 25–29. Halo effects have been studied in terms of people, companies and brands. Where positive views of certain attributes cause other attributes to be viewed favourably, halo effects are present. The effect can work in reverse (the horns effect) whereby a dislike of one attribute can create negative views of other attributes.

[59] Halo effects were not estimated for Sydney LRT or the Melbourne and NZ data. To apply the NSW halo effects to the VIC and NZ importance estimates, the ratio of the halo / direct effect estimated for NSW could be applied.

Table 39: Direct and Halo Effects of Vehicle Attributes – Sydney Rating Data

Vehicle Attribute	Bus			Rail			Ferry		
	Direct	Halo	Total	Direct	Halo	Total	Direct	Halo	Total
Outside Vehicle Appearance	12%	11%	23%	7%	10%	17%	14%	12%	26%
Ease of Getting On-Off	9%	11%	20%	11%	8%	19%	21%	13%	34%
Seat Availability & Comfort	9%	7%	16%	10%	9%	19%	12%	11%	23%
Space for Bags	2%	6%	8%	1%	7%	8%	5%	6%	11%
Smooth & Quietness	10%	12%	22%	8%	13%	21%	10%	10%	20%
Heating & Air Conditioning	8%	8%	16%	6%	6%	12%	6%	5%	11%
Lighting	7%	10%	17%	9%	11%	20%	5%	8%	13%
Cleanliness & Graffiti	16%	10%	26%	10%	7%	17%	12%	10%	22%
On-board Information	3%	4%	7%	5%	6%	11%	4%	3%	7%
WIFI- Internet Connectivity	0%	1%	1%	4%	4%	8%	2%	4%	6%
Driver / Staff	16%	6%	22%	6%	4%	10%	na	na	na
Environment Impact	8%	4%	12%	5%	5%	10%	4%	5%	9%
Toilet Availability & Cleanliness	na	na	na	2%	0.03	5%	na	na	na
Onboard Food/Drink	na	na	na	na	na	na	5%	1%	6%
Train Layout	na	na	na	11%	0.08	19%	na	na	na
Personal Security	na	na	na	5%	0.08	13%	na	na	na
Total	100%	90%	190%	100%	109%	209%	100%	88%	188%

Returning to the 20% improvement in seat rating for a train with an overall rating of 60%. From Table 39, the halo effect is 9%. The halo effect is added to the direct effect (importance share) of 10% to get 19%. Multiplying the 20% improvement by 19% gives an increase in the overall train rating of 3.8%. Applying the power transformation to the base overall rating of 60% and the new predicted rating of 63.8% gives a transformed difference of 3.1%. For a 35 minute onboard rail trip, the improvement would be worth 3.1% of 23.7 minutes (Table 37) which is 0.73 minutes. Thus the halo effect nearly doubles the value of the improvement from 0.4 minutes to 0.73 minutes.

For improvement packages involving more than one attribute, including halo effects becomes complicated. This is because the 'halo' effect must reduce as more attributes are added. In the extreme, if all attributes were improved by 10%, the overall vehicle rating must also increase 10%. It could not increase by 19% as would be the prediction if the rail halo values in Table 39 were added. Thus as more attributes are added, the halo effect only affects those attributes left unimproved (plus those attributes improved to a lesser degree).

Table 40 sets out the calculation for a package of improvements. The estimate involves 12 'rows' of calculations and could be set up in a spreadsheet. The example is for rail and involves a 5% improvement in smoothness/quietness, 20% improvement in heating/air conditioning and 10% increase in lighting rating.

The result is a 4.7% increase in the overall train rating. This result compares with 2.5% if only direct effects had been included (row 3) and 5% had the unadjusted halo effect been used (2.5% in row 5 + 2.5% in row 3).

If packages involve reductions as well as increases in rating then it is recommended that positive and negative effects are calculated separately and then added together.

Table 40: Calculation of Halo Effects of Package Improvement

#	Description	Formula	Example
1	Predict the change in rail attribute rating (example is smoothness /quietness (SQ), heating/air conditioning (AC) & lighting (LT))	Ai	SQ = 5% AC = 20% LT = 10%
2	Calculate the direct effect by multiplying the rating increase by the direct importance percent in Table 39	Ai x Di	SQ: 5% x 14.5% = 0.73% AC: 20% x 7% = 1.4% LT: 10 x 2% = 0.2%
3	Calculate the total direct effect	SD=Sum(AixDi)	SD = 2.5% = 0.4% + 1.2% + 0.9%
4	Calculate the initial Halo effects by multiplying the rating increase by the respective halo effects in Table 39	Hi	SQ: 5% x 13% = 0.7% AC: 20% x 6% = 1.2% LT: 10% x 6% = 0.6%
5	Calculate the total halo effect	SH=Sum(Hi)	SH = 2.5% = 0.7% + 1.2% + 0.6%
6	Calculate weights for the direct effects	Wi=Di/SD	SQ: 0.4%/2.5% = 16% AC: 1.2%/2.5% = 48% LT: 0.9%/2.5% = 36%
7	Calculate the change in weighted rating	WR= SUM(Ai x Wi)	14% = 5% x 16% + 20% x 48% + 10% x 36%
8	Calculate the maximum halo effect	MaxH = Max[Hi]	1.2% = Max[0.7%,1.2%,0.6%]
9	Calculate the residual halo effect	ResH = WR - MaxH	12.8% = 14% - 1.2%
10	Calculate the halo adjustment factor	Hadj= 1 - {(SH - MaxH)/ResH}	0.9 = 1 -{(2.5% - 1.2%)/12.8%}
11	Calculate the adjusted halo effect	AdjH=Hadj x SH	2.2% = 0.9 x 2.5%
12	Calculate the change in overall rating	ΔR=SD+AdjH	4.7% = 2.5% + 2.2%

8.4 Variation in Vehicle Ratings

The NZ, NSW and Victoria surveys provided passenger ratings on different types of bus, train, tram/Light Rail and ferry. In so doing, the data provides a benchmark for assessing the likely change in rating for particular proposals.[60]

Altogether, ratings for 110 vehicle types (with an acceptable sample size) were surveyed between 2012 and 2014. The vehicle types comprised 92 bus, 19 train, 6 tram and one LRT plus 8 ferry.[61]

[60] Ideally, rating surveys should be undertaken for a particular project to assess ‘base’ vehicle quality.

[61] The term type is used loosely as the grouping of the vehicles surveyed varied. For bus, only the NZ survey recorded the identification code of the buses to enable the details of the buses such as age, seating, engine type to be determined and used to explain the variation in the ratings given by passengers. Sydney buses were classified by route. 90 routes were surveyed and 66 provided samples > 20.

Table 41 provides details of the vehicles surveyed.

26,094 passengers completed a questionnaire. NSW (Sydney, Newcastle and Wollongong) provided 12,389 responses (47% of the sample); NZ (Auckland, Christchurch and Wellington) 11,990 responses (46%) and Victoria (Melbourne) 1,715 responses (7%).

Table 41: Details of the 2012-14 NZ, NSW and Victoria Vehicle Rating Surveys

		Vehicle Type					Response				
Loc	Year	Bus	Train	Trm/L	Ferry	ALL	Bus	Train	Trm/L	Ferry	Total
NZ	12-13	25	7	-	-	32	7,155	4,835	–	–	11,990
VIC	14	2C	3	7	-	12	533	710	472	–	1,715
NSW	12-14	66R	9	1	8	84	3,365	5,811	820	2,393	12,389
Total	–	93	19	4	8	128	11,053	11,356	1,292	2,393	26,094

Notes: C is 2 categories Smart & Standard; A denotes areas/routes Sydney, Newcastle, Wollongong; Trm/L denotes tram and light rail

Since the surveys were undertaken, vehicle fleets have changed. The Auckland rail network has been as electrified with Electric Multiple Units (EMUs) replacing Diesel Multiple Units (DMUs); the Wellington trolley bus network has been dismantled; double decker buses were introduced into Sydney, Auckland and Wellington (some battery powered) and single decker EMUs were introduced onto Sydney Metro.

Surveyors handed passengers a questionnaire to complete during their bus, train, tram or ferry trip. The questionnaires were similar but differed slightly by mode and location.

In NZ, fieldworkers recorded the identification details of the buses they surveyed so that the age, number of seats, engine class, floor height and other details could be later determined to help explain the passenger ratings.[62] The bus ratings were classified into 25 bus types where the number of responses exceeded 10. Some of the surveyed buses are presented in Figure 31.

Seven NZ train types were surveyed (see Figure 32). Auckland diesel trains were either loco hauled (SA or SD sets) or diesel rail cars (ADL or ADK). The SA or SD sets were ex British Rail carriages refurbished in 2005 (new windows, battery equipment, air conditioning units and recycled bogies) and scored 69%. The ADL and ADK diesel units were imported from Perth in 1993 (built 1982-85) refurbished in 2002-3 and rated at 66%.

Wellington trains comprised Matangis and Ganz Mavag electric multiple units (EMUs) and diesel loco hauled carriages. The Matangi EMUs had just been introduced when surveyed and had side seating in low floor areas (to increase standing capacity) next stop displays and recorded announcements; they rated at 82% (the highest NZ vehicle rating). The Ganz Mavag EMUs were at the end of their life when surveyed. They had entered service in 1982-83 and had been last refurbished in 1999-2003. At 59%, they rated the lowest of the NZ trains surveyed.

Diesel hauled carriages were used on the long distance Wellington-Wairarapa line. The carriages were ex British Rail (Mark 2D and 2F stock) rebuilt in 2007 and had next stop displays and recorded announcements. The seats had pull down tables with some four seat table arrangements. Power was provided for computers and a key for WIFI. The trains had onboard toilets and a baggage car able to carry bicycles. The rollling stock scored 78%.

[62] Auckland Transport, Environment Canterbury, Greater Wellington Regional Council and Mana Coaches provided details of the bus and trains fleets.

Figure 31: Types of Bus Surveyed in Auckland, Christchurch & Wellington

ADL bus used on Inner Loop Service and City Link services and also on the Outer Loop. The ADL scored 75% overall. The three services rated highly; the Inner Loop / City Link scored 79% and the Outer Loop 83%.

Scania 280D used on the Wellington Airport Flyer had 47 leather seats, luggage space & stop information rated at 79%

Scania K270 used on the Auckland Northern Express was low floor and wheelchair accessible and rated at 78%.

Wellington trolley buses (powered by overhead electricity) had 43 seats and were 3 years old. Rated 73%

Most Christchurch buses surveyed had a bike rack.

A 30 year old articulated MAN SG220 with 76 seats was surveyed on south Auckland routes and rated at 66%

A Volvo B10 used in Wellington was 29 years old rated at 37%.

Figure 32: Trains Surveyed in Auckland and Wellington

Auckland SA/SD diesel loco-hauled (ex British Rail) rolling stock refurbished in 2005 rated 68-69%.

Auckland ADL/ADK rolling stock (ex Perth) refurbished 2002-3 rated 66%

The Wellington Matangi EMUs were 1 year old when surveyed and rated 82%

The Wellington Ganz Mavag EMUs which were being withdrawn when surveyed rated 59%

Diesel Loco hauled carriages (ex British Rail) refurbished in 2007 rated 78%

The 2014 Melbourne study surveyed 2 types of buses, 7 types of tram and 3 types of train as summarised in Figure 33.

At 1,715 responses, the survey was noticeably smaller than the NZ and NSW surveys.[63] Identification details were not recorded for buses with vehicles classified into Smart or Standard buses. Smart buses had better passenger information and rated at 73% which was 2% points more than the 71% rating of standard buses.[64]

---

[63] A main aim of the Victoria study was to value tram passenger information provided onboard and at-stops, see Douglas (2019).

[64] The buses were surveyed on three orbital and four 'rapid' transit (Manningham-City) routes

Figure 33: Vehicles Surveyed in Victoria in 2014

	**SmartBus bus** used on 3 orbital & 4 Rapid Transit Manningham-City routes (#s 703,900-908). Use low-floor vehicles. Some stops have RTI & features for visually impaired. 15 buses surveyed.		**A class Tram. Single vehicle** tram seating 40. Introduced from 1988. No onboard electronic info. 3 vehicles surveyed.
	**Standard bus** - variable details. 23 buses surveyed.		**Z class Tram.** Narrow front end single vehicle tram seating 40. Introduced from 1978 onwards. No onboard electronic information. 12 vehicles surveyed.
	**E class Tram.** Bombadier. Newest tram introduced from 2012. Articulated, 4 sections each seating 64 pax. Has electronic onboard information. Only one vehicle surveyed.		**W class tram.** Heritage tram used on city circle. Introduced circa 1952. Seats 52.No onboard electronic information but has a manual bell. 1 tram surveyed.
	**D class Tram.** (D1&D2) Combino tram introduced from 2002. Articulated, 4 sections each seating 58 pax. Has electronic onboard information. Introduced from 2002. 2 vehicles surveyed.		**X'Trapolis train.** Alstom introduced 2002. 3 car units 264 seated 133 std (crush 697). 16 vehicles surveyed.
	**C class Tram** (C1&C2) Citadis tram. Articulated, 5/3 sections each seating 54/40 pax. Has electronic onboard information. Introduced from 2002. 3 vehicles surveyed.		**Siemens Nexas train.** Introduced from 2002. 3 car set, seats 264. 19 vehicles surveyed.
	**B class Tram (B1&B2)** ComEng built. Wide front - double articulared tram seating 74/76. Introduced from 1990. No onboard electronic info. 17 vehicles surveyed.		**Comeng train.** Introduced from 1981. Refurbished 2002 with two variants Connex and EDI. 16 Alstom trains surveyed and 9 EDI.

Seven types of Melbourne 'tram' were surveyed. Light Rail like trams (E, D and C) rated 73%. The E class 1-2 year old Bombadier articulated 64 seat 4 section vehicles with next stop information rated 77%. The C class Citadis and D class Combino vehicles introduced from 2002 rated 75% and 69% respectively.

The single car A class trams (26 years old) seating 40 scored 64% and the B class 75 seat 2 car trams (30 years old) scored 66%. The Z class single car 40 seater trams introduced from 1978 (36 years old) scored 62%. The oldest tram was a 1952 W class used on the Melbourne city circle route; it obtained the highest rating of 84% reflecting its vintage qualities.

Three train types were surveyed. They were all were electric single deck units. The X'Trapolis 3 car units (264 seated) introduced from 2002 and refurbished in 2009 scored 67%. The 3 car Siemens Nexas introduced from 2002 rated 65% and the Comeng introduced from 1981 and also refurbished in 2002 scored 60%.

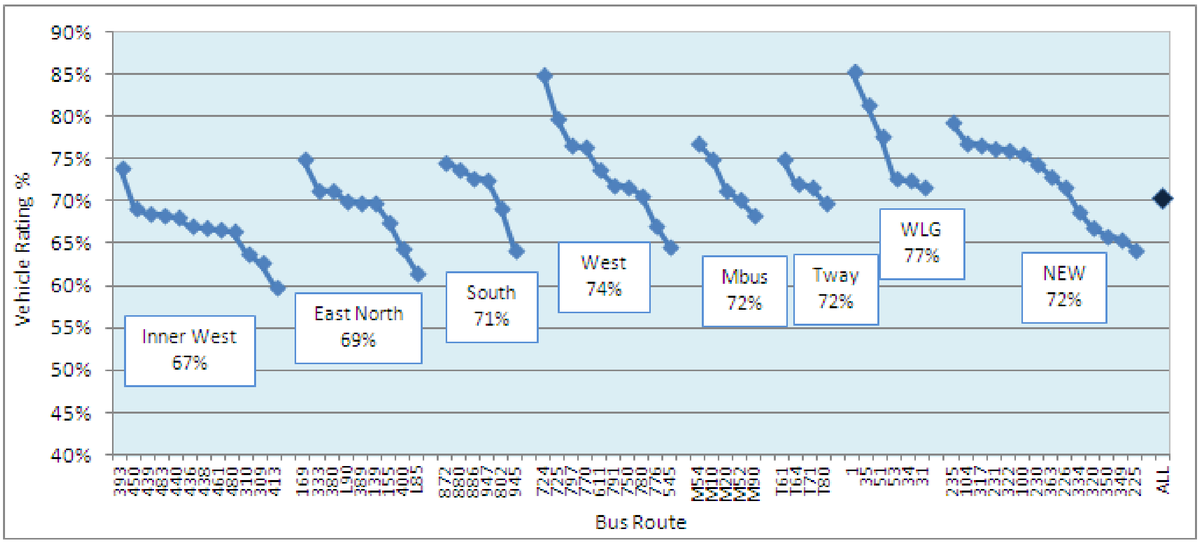
The NSW survey surveyed bus, trains, ferries and the Darling Harbour Light Rail.

360 bus services on 61 routes were surveyed. The routes were classified into eight 'segments'. The range in rating was wider by bus route (60% to 85%) than segment (67% to 77%) as can be

seen from Figure 34 which reflects a smaller samples amongst other things.[65]

Wollongong buses rated the highest at 77%. Metrobus pre-pay M10 services (eg Maroubra-City-Leichardt) that used 5 year old articulated 3 door 64 seat buses) rated 72% which was the same as the buses used on Transitway services (e.g. Parramatta-Liverpool). The lowest ratings for Inner West buses which averaged 67%.

Figure 34: NSW Bus Vehicle Ratings (2012-2014) aggregated by Bus Route and Segment



The one LRT service operating in Sydney in 2013 was surveyed. The Central – Darling Harbour - Lilyfield Light Rail service was operated by low floor, 2 car set German Variotrams with 219 passenger capacity per car (74 seated 145 standing). The Variotrams had been introduced in 1997-98 (15 years old when surveyed) and achieved an 81% rating.[66]

Nine train types were surveyed, see Figure 35. Eight were double deck, EMUs (usually in eight car sets). The exception was the 20 year old Endeavour DMUs used on outer -suburban services that rated at 64%.

The Waratahs (A) were the newest trains (less than 4 years old) with a wider entrance for faster boarding/alighting; LED lighting; next stop information; internal and external security cameras and scored 73%. The Millennium introduced 2002-05 (7-12 years old) rated 70%.

The Tangaras introduced between 1988 and 1994 and refurbished 2012 rated 66%.

The Oscar and V sets used on outer-suburban / intercity services were surveyed. The Oscars were relatively new (between 1 and 6 years old) and scored 72%. The older V sets (between 25-35 years old) rated at 62%.

The oldest trains were the 30 year old C/K and S sets used mainly during the peak. The air-conditioned C/K sets rated 54% and the non-air conditioned S sets 48%.

---

[65] In Table 42, the maximum and minimums are calculated on the route ratings which had a wider range than the segment ratings.

[66] The Variotrams were withdrawn around 2015 and replaced by Urbos 3 Light Rail Vehicles.

Figure 35: NSW Train Types Surveyed

Waratah (A set)

Millennium (M set)

OSCAR (H set)

Tangara (after refurbished 2012)

Tangara (Pre-refurbish)

C/K Sets (Air-conditioned)

S Sets (Non Air-conditioned)

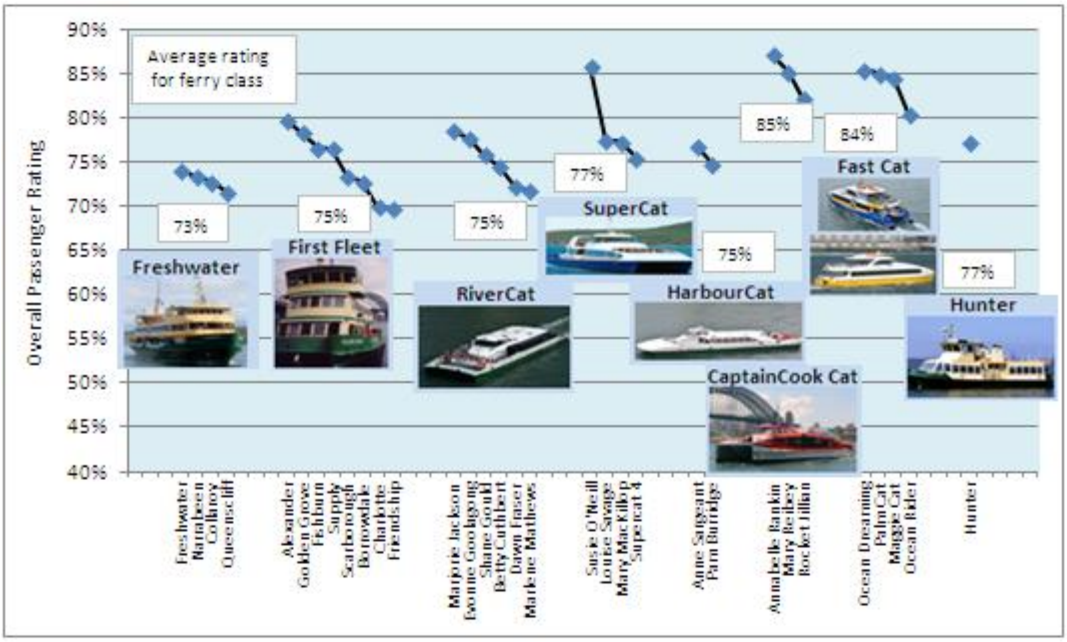
V Sets

Endeavour

Photos courtesy of Wikipedia.

32 Sydney and Newcastle ferries were surveyed that were grouped into 8 classes. The ratings for all the ferries were relatively high when compared with the bus and train ratings ranging from a low of 73% to a high of 85%. Figure 36 show the ferries and ratings. The lowest rated were the large 30 year old Manly Freshwater class ferries (73%) whereas the smaller privately operated Manly fast ferries scored 84%.[67]

Figure 36: NSW Ferry Ratings (2014) aggregated by Ferry Class



The 'First Fleet' ferries (28 years in service) operated the Inner Sydney Harbour and rated at 75% which was the same as Harbour Catamarans (24 years) that provide back-up.

The highest rated ferries with an average overall rating of 85% were the four newly contracted Captain Cook Catamarans operating Parramatta River services. The older River Cats (20 years old) operating on the Parramatta River services scored 75%. The Supercats (10 years old) that serve the Eastern Suburbs scored 77%. The Hunter catamaran (25 years old) operating the short (2-3 minute) Newcastle - Stockton estuarine service scored 77%.

Table 42 combines the vehicle ratings from NZ, NSW and Victoria together to provide a set of 'benchmark' ratings. As well as the overall rating, the ratings for individual vehicle attributes are presented.[68]

The average figures were calculated by averaging the NZ, NSW and Victoria figures (no weighting). The maximum and minimums provide a benchmark for assessing the biggest effect from a vehicle improvement.

[67] Ages of the private ferries were not known.

[68] There were some differences in the list of attributes included on the different questionnaires.

Table 42: Average, Maximum and Minimum Vehicle Ratings by vehicle type

NZ, NSW and Victoria 2012-2014 Surveys

Attribute	Average Rating					Bus		Tram/LRT		Rail		Ferry		All	
	Bus	TrmL	Rail	Ferry	All	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Outside Appearance	73%	74%	67%	75%	72%	88%	55%	81%	62%	84%	46%	85%	69%	88%	46%
Ease of On & Off	77%	77%	75%	81%	78%	89%	55%	83%	66%	84%	65%	90%	78%	90%	55%
Seat Avail & Comfort	75%	74%	71%	79%	75%	89%	59%	82%	69%	80%	54%	86%	74%	89%	54%
Space for Bags	67%	64%	65%	73%	67%	84%	53%	71%	59%	74%	37%	77%	64%	84%	37%
Smooth & Quiet	65%	71%	66%	76%	70%	84%	54%	77%	62%	80%	50%	85%	67%	85%	50%
Heating & Air Con	70%	72%	69%	71%	70%	88%	44%	78%	57%	78%	38%	81%	60%	88%	38%
Lighting	74%	77%	75%	76%	75%	91%	61%	82%	68%	84%	56%	85%	71%	91%	56%
Inside Clean & Graf.	72%	77%	68%	81%	74%	92%	58%	84%	65%	87%	53%	92%	74%	92%	53%
Information	59%	66%	67%	73%	66%	76%	38%	74%	55%	78%	48%	84%	53%	84%	38%
Computer & Internet	46%	61%	49%	60%	54%	72%	12%	71%	50%	58%	30%	67%	55%	72%	12%
Driver/Staff	71%	77%	66%	-	72%	92%	65%	82%	69%	81%	59%	-	-	92%	59%
Environ Impact	66%	71%	60%	73%	67%	84%	44%	77%	58%	72%	43%	76%	62%	84%	43%
Toilet Avail & Clean	-	-	59%	-	59%	-	-	-	-	76%	27%	-	-	76%	27%
Ticket Purchase#	70%	-	-	-	70%	71%	69%	-	-	-	-	-	-	71%	69%
Food/Drink+	-	-	-	78%	78%	-	-	-	-	-	-	76%	76%	76%	76%
Personal Security^	-	-	68%	-	68%	-	-	-	-	72%	59%	-	-	72%	59%
Train Layout^	-	-	68%	-	68%	-	-	-	-	81%	53%	-	-	81%	53%
Overall Rating	71%	74%	68%	78%	73%	85%	37%	84%	62%	82%	48%	85%	73%	85%	37%

^ Sydney Trains; + fast Manly ferry; # onboard Melbourne bus ticket purchase

Sydney Ferries were the highest rated vehicles with an average overall rating of 78%. Trams/Light Rail were second on 74%. Buses averaged 71% with rail the lowest rated on 68%. The simple average rating for the four modes was 73%.

The highest rated type of vehicle was the Captain Cook Catamaran on 85% followed by the Melbourne vintage tram on 84% and the Wellington Matangi train on 82%. The highest rated bus was the Auckland BCI bus which scored 79%.

The lowest rated vehicle was a 29 year old Volvo B10 bus used in Wellington on 37%. The lowest rated train was the non air-conditioned Sydney S set on 48%. The lowest rated tram was the 26 year old single car Melbourne A class (62%) and the lowest rated ferry was the Manly Freshwater class although at 73% they were still rated relatively highly by passengers.

Ease of boarding and alighting tended to be the highest rated attribute averaging 78%. Computer and internet availability was the lowest rated attribute on 54%.

8.5 Explaining the Variation in the NZ Vehicle Ratings

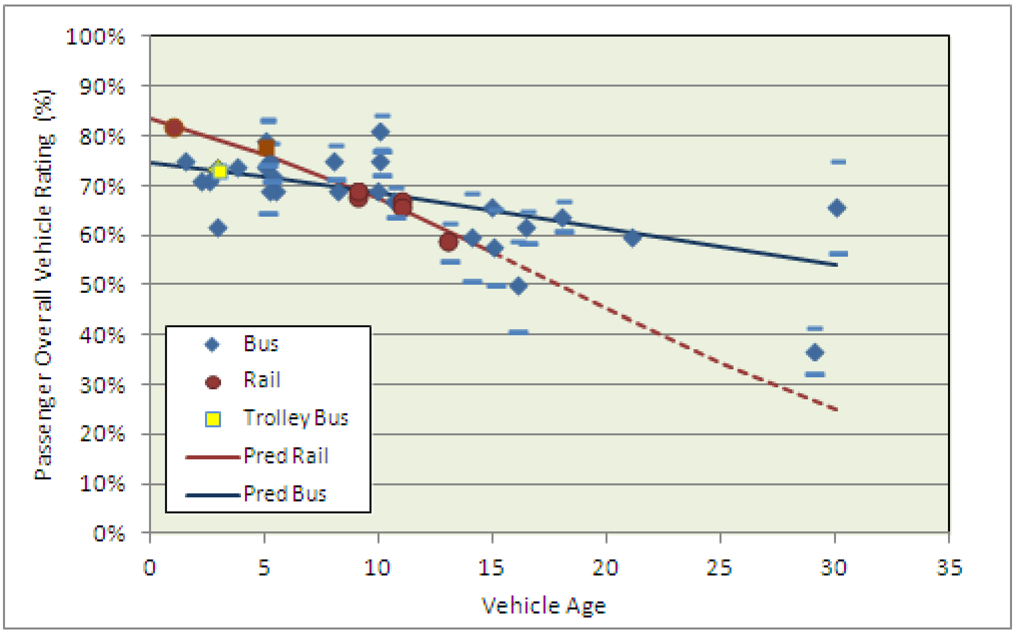
The large NZ sample and the recording of bus details enabled explanatory models to be fitted to explain the variation in vehicle ratings in terms of vehicle age, seat capacity, euro engine rating, air conditioning, floor height, wheelchair access, bicycle racks and premium branded bus routes. In addition, the characteristics of the passenger and the trip were also taken into account.

Each factor was analysed separately using regression and then assessed with other factors using multiple regression. The correlation between factors e.g. age and engine standard meant that some parameters were statistically insignificant.

Vehicle rating declined with age although the sampling error was quite wide as can be seen from Figure 37. The predicted passenger rating was 75% for a brand new bus. After 5 years, the rating declined to 72% and to 67% at 10 years and 65% at 15 years. Therefore over 15 years, the rating declined by 10%.

Figure 37: Effect of Vehicle Age on Bus and Train Overall Passenger Rating

2012-2014 Auckland, Christchurch and Wellington Survey



The analysis was not 'time-series' by tracking the same bus over 15 years but 'cross-sectional' by comparing different buses of different ages. In doing so, features that newer buses have that older buses have not are included in the age relationship which will inflate the effect of age in a pure sense. New buses are more likely to be air conditioned, super low floor, wheel chair accessible and have a higher environmentally rated engine than the old buses that were surveyed.

For NZ trains, the decline in overall rating was more pronounced falling from a rating of 84% for a new train to 76% after 5 years and 67% after 10 years. Apart from the Wellington Matangi train, the age of the train was measured from the last major refurbishment (rather than the age since built). This was because three of the five train types were second-hand imports that were majorly refurbished in NZ.

Figure 38 depicts an approximately linear relationship. To keep the predicted rating between 0%

and 100%, logistic functions were fitted for bus and rail separately.[69] The predicted function is graphed and for rail is shown as a dotted line for trains 15 years after refurbishment to emphasise it is an extrapolation.

$$Z = \ln\left[\frac{\Pr R}{1-\Pr R}\right] = \alpha + \beta_{age} AGE \text{ .....(8.3)}$$

Bus Z = 1.083 - 0.031*AGE* *OBS = 28*
(12.2) (2.5)

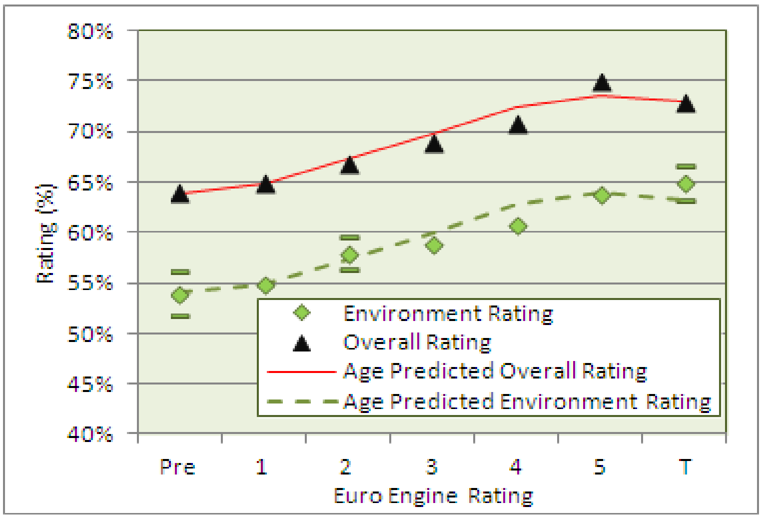
Rail Z = 1.633 - 0.092*AGE* *OBS = 7*
(79.2) (27.8)

Seat capacity was assessed on the overall vehicle and seat availability and comfort rating. Increasing seat capacity increased the predicted rating after standardizing for bus age. A new bus with 20 seats was predicted to have an overall vehicle rating of 69% and a seat availability and comfort rating of 74%. Doubling seats to 40 increased the overall rating to 75% and the seat availability and comfort rating to 80%. Tripling seats to sixty produced ratings of 81% and 86% respectively.

Buses were classified by European emission standard[70] Buses were classified as 'pre rating', into five Euro standards and the electric Wellington trolley buses and used to explain the overall vehicle and the environmental rating.

The environmental and overall ratings increased with Euro engine rating. At 65%, the Wellington trolley bus (denoted T) had the highest environmental rating. The Euro 5 bus was second on 64%. The lowest environmental rating was 54% for 'pre rating' buses.

Figure 38: Overall Bus and Environmental Rating with Euro Engine Standard



[69] The observations were weighed in accordance to their relative t values whilst maintaining the number of observations.

[70] Euro standards define the acceptable limits of exhaust emissions for new buses and cover carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), particulate matter (PM) and smoke. Since 1992, there have been five Euro engine standards.

The overall bus rating followed a similar trend but was higher. The rating increasing from 64% for 'pre rated' buses to 74% for a Euro 5 bus. The 100% electric Wellington trolley bus rated 73%.

The relationship between engine rating and age was close as can be seen from the predicted age based ratings in Figure 38 (estimated by equation 8.3).

Air conditioned buses which also tended to be newer rated higher (72%) than non-air conditioned buses (68%). The difference in the heating/air conditioning rating was only slightly wider at 68% versus 63%.

Buses classified as low floor had no steps at the door making them easier to get on and off especially for the elderly or infirm, passengers in wheelchairs and passengers with strollers/heavy luggage etc.[71] 96% of bus respondents were surveyed on low floor buses.[72] They rated the ease of getting on and off at 77% and rated the overall vehicle at 70%. Non low floor buses had either one or two steps and tended to be older (18 years compared to 7 years in service). The 4% of respondents on non-low floor buses rated the ease of getting on and off 9% points lower at 68% and the overall vehicle 6% lower at 64%.

Bicycle racks were only installed on Christchurch buses. All but 47 Christchurch respondents (4%) were surveyed on buses with bike racks.[73] The overall vehicle rating for buses with bicycle racks was 7% higher than buses without bicycle racks (67% versus 62%). The buses with bike racks tended to be younger however (5.5 years versus 12.5 years).

Five of the surveyed bus routes were considered 'premium' using newer buses (3 years old) branded livery and having better onboard information than standard buses (7.7 years old). Premium routes were the Wellington Airport Flyer; the Auckland Link, Inner and Outer Loop services and the Auckland Northern Express.

Premium buses rated 11% points higher in outside appearance rating than standard buses (82% versus to 71%). The difference in onboard information and announcement rating was wider at 24% points (78% versus 54%). The overall vehicle rating was 20% points higher (79% versus 69%) than for standard buses. It was also 6% higher than if predicted purely on the basis of bus age (3.1 years compared to 7.7 years).

Table 43: Ratings for Premium versus Standard NZ Bus Routes

Bus	Vehicle Age	Overall Rating		Attribute Rating		Sample Size		
Route	Years	Average (%)	Pred Age	OS App	Info	Overall	OS App	Info
Premium	3.1	79%	73%	82%	78%	599	217	212
Standard	7.7	69%	70%	71%	54%	6,556	3,203	3,174
All	7.4	70%	70%	71%	55%	7,155	3,420	2,962

Multiple regression was used to determine the most important variables explaining the variation in the overall vehicle rating across respondents (11,990 observations). Linear and logit models were fitted. The linear model is easiest to interpret as the parameters are the difference in rating. The

71 The data did not distinguish between buses that 'kneel' at stops thereby making the bus level with the curb or buses that have no raised rear part of the bus

72 Nearly all the low floor buses surveyed were also classified as wheelchair accessible by the regional authorities

73 25 out of 33 buses that were surveyed were fitted with bicycle racks. Some buses were surveyed more than once.

logit model constrains the predicted rating to between 0% and 100%.[74]

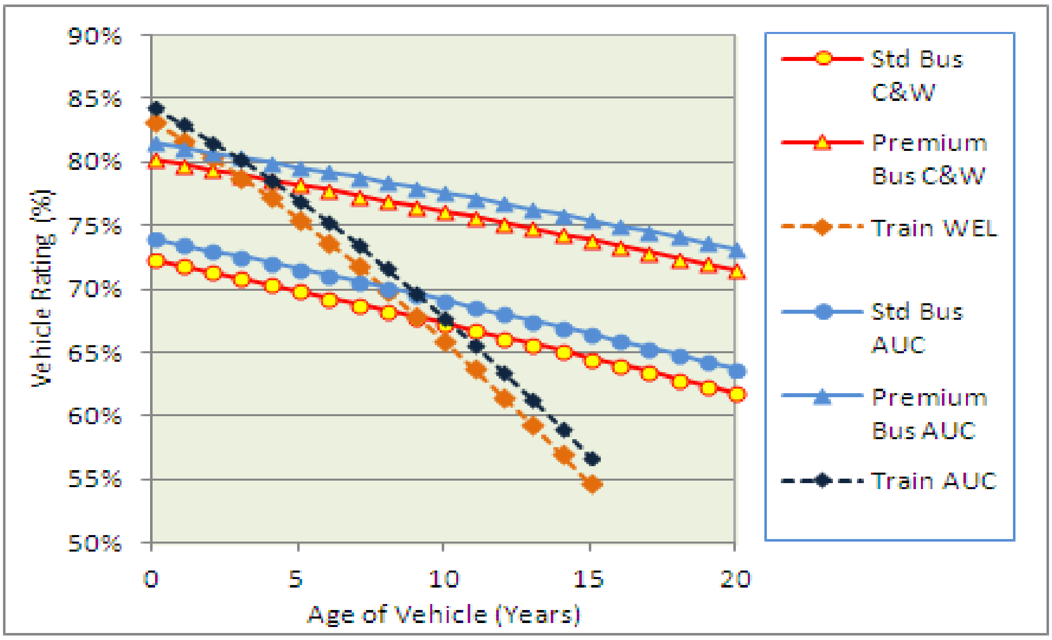
Seven variables were statistically significant. Buses tended to be rated lower than trains. Vehicle age (years) reduced the rating with the decline slower for buses than trains. Adding seats increased the bus rating. Premium bus routes increased the rating by 8% points. The Wellington trolley bus rated 2.3% points higher. Auckland respondents rated 2% higher than Wellington and Christchurch respondents.

Table 44: Overall Vehicle Explanatory Model – Vehicle Variables

Variable	Linear			Logit		
	Beta	STE	|t|	Beta	STE	|t|
BUS	-0.171	0.018	9.5	-0.890	0.093	9.6
AGE	-0.018	0.001	30.0	-0.094	0.003	31.4
BUS*AGE	0.013	0.001	17.1	0.070	0.004	18.1
BUS*SEATS	0.001	0.0004	2.6	0.006	0.002	3.0
BUS * Premium	0.08	0.009	8.9	0.438	0.054	8.1
Auckland	0.019	0.004	4.8	0.083	0.020	4.2
Trolley Bus	0.023	0.011	2.1	0.107	0.055	2.0
Constant	0.838	0.004	209.5	1.600	0.022	72.7

Figure 39 graphs the predicted rating with vehicle age (Trolley buses omitted). Bus ratings declined more gradually with age than trains. For Wellington, the rating declined from 72% for a brand new standard bus to 67% (5% points) after ten years compared to 83% to 66% (17% points) for a train. Premium bus routes shifted the rating curve upwards by 8% points.

Figure 39: Predicted Overall Vehicle Rating with Age & Vehicle Type



[74] The transformation produces logit parameters that are six times larger than the linear regression parameters.

The characteristics of the respondent were also used to explain the vehicle ratings. Characteristics included time of travel, journey purpose, gender, socio-economic status, age group, and frequency of use. The characteristics that were found to be statistically significant were included alongside the vehicle variables in Table 44 to develop the overall model presented in Table 45.

Table 45: NZ Vehicle Rating Model with Vehicle & Passenger Characteristics

Variable	Linear			Logit		
	Beta	STE	|t|	Beta	STE	|t|
Bus	-0.169	0.018	9.4	-0.881	0.093	9.5
Vehicle Age (years)	-0.0188	0.0006	30.8	-0.097	0.003	32.3
Bus*Age (years)	0.014	0.001	18.7	0.073	0.004	18.3
Bus * Seats (number)	0.0012	0	3.1	0.005	0.002	2.5
Bus * Premium Bus Route	0.067	0.009	7.4	0.375	0.054	6.9
Auckland	0.024	0.004	6	0.107	0.02	5.4
Trolley Bus	0.027	0.011	2.5	0.129	0.054	2.4
PM Peak	-0.024	0.004	6	-0.116	0.021	5.5
Entertainment/Holiday	0.038	0.007	5.8	0.195	0.035	5.6
Visit Friends Relatives	0.018	0.006	2.9	0.089	0.032	2.8
Female	0.016	0.003	5.3	0.079	0.018	4.4
Retired	0.055	0.007	7.4	0.298	0.041	7.3
Aged under 18	-0.035	0.006	6.3	-0.168	0.028	6
Aged 18 - 24	-0.019	0.004	4.8	-0.093	0.021	4.4
Constant	0.837	0.068	12.3	1.596	0.025	63.8

Seven of the passenger and trip profile variables were statistically significant (t>|1.96). Retired passengers rated vehicles 5.5% higher than non-retired passengers whereas passengers aged under 18 gave ratings 3.5% lower and passengers 18-24 rated 1.9% lower. Passengers travelling in the PM peak gave ratings 2.4% lower whereas passengers making entertainment/holiday trips and passengers visiting friends or relatives gave higher ratings (3.8% and 1.8% respectively). Females gave ratings 1.6% higher than males. Their introduction had only minor impact on the vehicle variable parameters. For instance, the bus age parameter changed slightly from -0.019 to -0.018 in the linear model.

8.6 Trends in Sydney Train Ratings

Rating surveys of Sydney rail have been conducted over a 20 year period. In addition to the three surveys conducted between 2012 and 2014 that were discussed previously there were two earlier surveys. The first was in 1994 and the second in 2004. Altogether, 9,745 ratings were obtained covering eleven train types. Table 46 presents the train ratings for the 5 surveys.

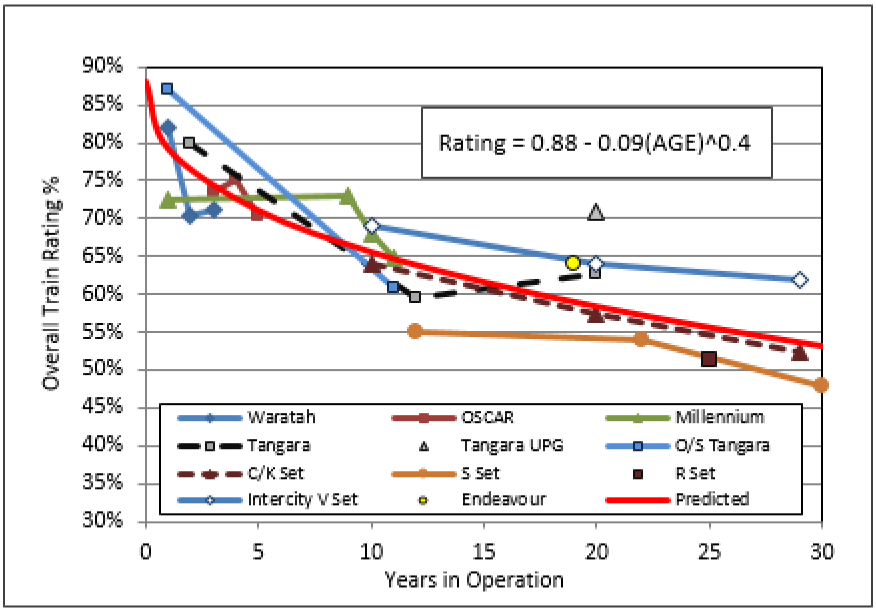
Table 46: Sydney Overall Train Rating by Train Type & Survey

Class	Train Type	Rating (%)					Sample Size (N)			
		1994^	2004	2012	2013	2014	2004	2012	2013	2014
A	Waratah	na	na	82%	70%	71%	na	264	546	840
H	Oscar	na	na	74%	75%	70%	na	203	20	202
M	Millenium	na	72%	73%	68%	65%	284	289	246	74
T	Tangara	80%	59%	-	61%	67%	612	-	393	501
TR	Tangara Restored	na	na	71%	na	na	na	465	na	na
TU	Tangara Unrestored	na	na	63%	na	na	na	185	na	na
G	Tangara O/S	87%	61%	na	na	na	201	na	na	na
C	Air-conditioned	64%	57%	59%	-	57%	71	127	-	53
K	Air-conditioned		57%	59%	43%	54%	279	101	215	222
S	Non Air-conditioned	55%	54%	61%	44%	47%	490	110	339	76
R	Non Air-conditioned	51%	51%	na	na	na	276	na	na	na
V	Intercity V	69%	64%	64%	-	58%	448	196	-	119
D	Endeavour DMU	na	-	-	-	64%	-	-	-	25
ALL		68%	60%	70%	59%	66%	2,661	1,940	1,759	2,112

^ 1994 survey had a sample size of 1,273. All rating based on the average of the train type ratings.

The five surveys enabled the rating for an individual train type to be tracked over time. Figure 40 plots the train ratings against age. The decline in rating was steep over the first few years but then slackened off. To reflect this train age (in years from new) was raised to the power of 0.4. The rating of a brand new train was predicted at 88%. The rating then declined at 0.09 times the transformed age variable (number of years) which meant that after 5 years, the rating fell to 71% and to 66% after 10 years.

Figure 40: Effect of Age on the Rating of Sydney Trains



Age Yrs	0	5	10	15	20	25	30
Rating	88%	71%	66%	62%	58%	56%	53%

Given that newer trains tend to have more 'facilities' the model will tend to over-estimate the 'pure' age effect. For example, the Waratah has electronic passenger information, LED lighting and security cameras and is air conditioned. The older R/S sets had none of these facilities.

To take account of train type, a disaggregate model was fitted that used the individual passenger ratings for the 2004 to 2014 surveys (in a similar way to the NZ cross-sectional model).[75] Train type and passenger profile variables alongside train age were included to explain the variation in the passenger ratings. Table 47 presented the estimates for linear and logit specifications.

Five passenger profile variables were significant. Respondents travelling in the off-peak rated their train 1.6% higher than peak respondents. Retired passengers rated their train 4.6% higher than non-retired respondents. Passengers making personal business rated their train 2.2% higher, passengers visiting friends / relatives 5.3% higher and passengers making entertainment/holiday trips rated 4.6% higher than respondents making other trip purposes (mainly commuters and students). The findings were therefore similar to the NZ survey.

The effect of train age reduced. The estimated parameter of -0.039 was less than half that of the aggregate parameter value of -0.09 in Figure 40.

There was no significant difference in the rating of the three newest train types (Waratah, Millennium and Oscar) so these trains were grouped and treated as the 'base' train type.

Table 47: Sydney Train Rating Models

Variable	Linear		Logit	
	β	|t|	β	|t|
Off-Peak Period	0.016	3.3	0.071	3.4
Retired Passenger	0.046	5.0	0.217	4.8
Personal Business Trip	0.022	2.7	0.101	2.6
Visit Friends/Rels Trip	0.053	5.8	0.244	5.5
Entertainment/Holiday Trip	0.046	4.4	0.211	4.4
Train Age (years)^0.4	-0.039	7.0	-0.182	7.4
Tangara	-0.087	8.6	-0.287	8.9
Tangara (Restored)*	-0.091	10.8	-0.430	11.4
C/K Set	-0.099	7.0	-0.413	6.8
R/S Set (Non Air-conditioned)	-0.139	10.3	-0.575	9.9
V Set (Intercity)	-0.034	2.5	-0.155	2.7
Diesel Endeavour DMU	-0.047	1.1	-0.218	1.4
Constant#	0.773	77.1	1.201	26.0

Fitted on 8,486 Obs. Mean rating 64%, St. Dev 23%, R^2 = 0.15 (linear)

Base train type = Waratah, Oscar & Millennium

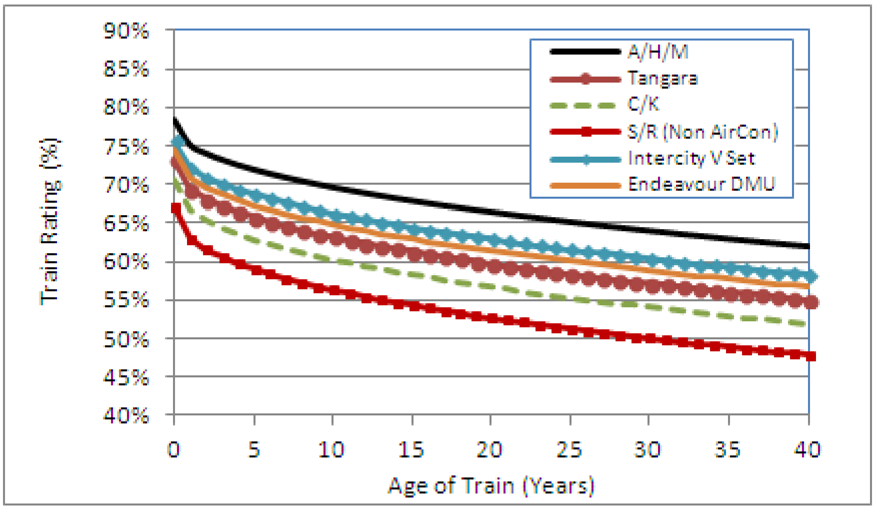
* Age of Restored Tangara in 2012=0; ^ Train Age raised to the power of 0.4

75 It was not possible to get the individual ratings for the 1994 survey.

Figure 41 plots the effect of age on the predicted train rating.[76] The predicted rating for a brand new Waratah, Oscar or Millennium was 78% which declined to 72% in year 5 and 66% in year 20.

The non-air conditioned R/S sets had the lowest rating. A 'new' R/S set was predicted to have a rating of 67% which declined to 53% after 20 years. The lower rating (11% points) reflects the lesser facilities and design compared to the Waratah, Oscar and Millennium trains.

Figure 41: Predicted Effect of Train Age on the Passenger Rating of Sydney Train Types



Train Type	Train Overall Rating (%) by Age of Train (Years)								
	0	5	10	15	20	25	30	35	40
A/H/M	78.3%	71.9%	69.6%	67.9%	66.4%	65.2%	64.0%	63.0%	62.0%
Tangara	73.1%	65.8%	63.2%	61.3%	59.8%	58.4%	57.2%	56.1%	55.1%
C/K	70.5%	62.9%	60.2%	58.3%	56.7%	55.3%	54.1%	53.0%	51.9%
S/R	67.1%	59.0%	56.3%	54.3%	52.7%	51.3%	50.0%	48.9%	47.9%
V Set	75.6%	68.7%	66.2%	64.4%	62.9%	61.6%	60.4%	59.3%	58.3%
END DMU	74.4%	67.3%	64.8%	63.0%	61.4%	60.1%	58.9%	57.8%	56.8%

The parameters in Table 47 were used to assess the effect of the refurbishing the Tangara fleet in 2011-13. The Tangaras were introduced between 1988 and 1994 so in 2011 and 2013 they were around 20 years old. The refurbishment was undertaken at a cost of $250,000 per car ($2 million per 8 car set). Figure 35 provided photos of the unrestored and restored Tangara.

The 2012 survey distinguished between the refurbished and unrefurbished Tangaras and estimated ratings of 63% and 71% respectively. The difference was therefore 8% percentage points.

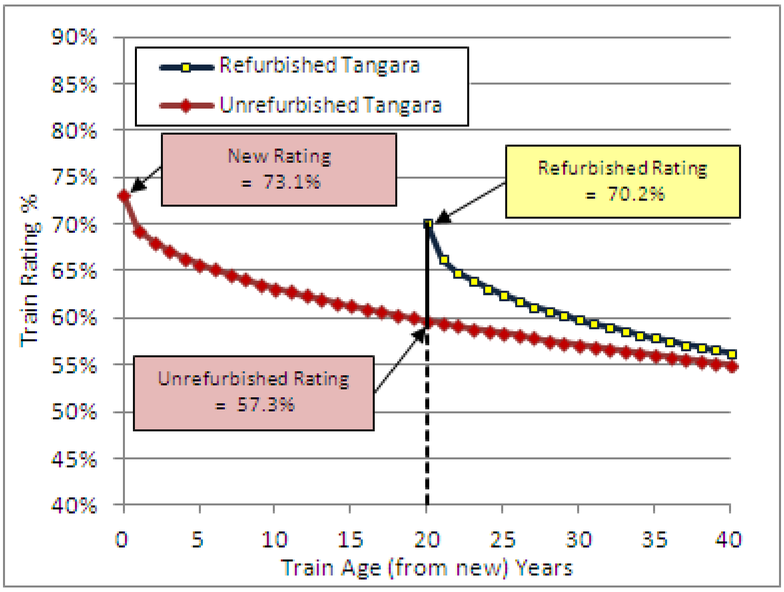
Figure 42 uses the parameters in Table 47 to predict the effect of refurbishing a 20 year old

[76] The passenger profile for peak travel was assumed to be 7% retired, 6% personal business, 5% VFR and 4% Ent/Hol. For the off-peak, the shares were 11%, 12%, 9% and 6% respectively. The peak share was 57% and the off-peak. By multiplying the shares by the parameters and summing the result the 'constant' adjustment was calculated. The train type and age parameters were then added. With the logit formulation, the predicted rating is exp(Z)/(1+exp(Z)) where Z is the sum of the trip and passenger profile variables, constant, train type parameter and transformed train age.

Tangara. The predicted rating for a brand new Tangara was 73.1%.[77] After 20 years, the rating declined to 59.8%. Refurbishment increased the rating by 70.2%, an improvement of 10.4% points.[78] The refurbished Tangara therefore rated 3% points less than a new Tangara (70.3% versus 73.1%).

The graph plots how the train rating declines over time. The gap between the refurbished and un-refurbished trains narrow such that in year 30 years, the difference is 2.7% points.

Figure 42: Predicted Effect of Tangara Refurbishment on Train Rating



8.7 Valuing vehicle attributes

Table 48 provides some examples of applying the valuation methodology to vehicle ratings obtained in the NZ, NSW and Victoria surveys. Examples of using the overall rating and different attribute ratings are provided. Absolute and percentage benefit values are given.

Three examples of new versus old trains are given. The value of passenger benefit ranged from 3.2 to 4.2 minutes (5% to 12.5% of IVT). The highest value was for the 90 minute intercity NSW example but it was also the lowest in percentage terms. The benefit of train refurbishment using the NSW Tangara was valued at 1.32 minutes.

A new E class tram was valued 1.34 minutes more than an old A class tram which was 6.7% of the average IVT of 20 minutes. The benefit of a new versus old bus (20 years) was similarly valued at 1.37 minutes. For ferry, the benefit of a fast cat versus a Freshwater class vessel for the 30 minute Circular Quay Manly service was valued at 2.52 minutes.

[77] It should be noted that the disaggregate model were estimated on the 2004-2014 ratings. The 1994 survey estimated a rating of 80% for the Tangara. The Millennium, Oscar and Waratah trains were not in service then. Had they been, these higher specification trains might have reduced the Tangara rating.

[78] The rating for the refurbished Tangara was predicted using the parameters in Table 47 (-0.43 logit model).

Table 48: Estimates of the value of vehicle quality

Mode	Comparison	Comparison A	Comparison B	Rating	Trip Length	Rating A	Rating B	IVT Valuation mins per trip	IVT Valuation percent of IVT
Rail	Wellington New v Old	Matangi	Ganz Mavag	Overall	30	82%	59%	3.74	12.5%
	Sydney Suburban New v Old	Waratah	C/K Set	Overall	30	73%	54%	3.19	10.6%
	NSW Intercity Trains	OSCAR	V Set	Overall	90	72%	62%	4.26	4.7%
	NSW Tangara Refurbish	Refurb	Unrefurb	Overall	30	71%	63%	1.32	4.4%
	Electric v Diesel	WEL Sub Rail	AKL Rail	Overall	30	78%	67%	1.81	6.0%
				Environmental	30	69%	53%	0.40	1.3%
	Onboard Info Display (VIC,NZ,NSW)	4 Ests (1)	4 Ests (1)	Information	46	76%	55%	0.46	1.0%
	Air-Conditioning 2 Ests	NSW C&K & WEL G.Mavag	NSW S Sets & WEL Matangi	Heating & Air Conditioning	30	67%	47%	0.55	1.8%
	Security CCTVs NSW	Waratah	Tangara & CK&S Sets	Personal Security	30	80%	67%	0.30	1.0%
	Onboard Staff NZ	WEL with ticketing staff	AKL with guards	Staff Avail & Helpfulness	30	76%	68%	0.31	1.0%
	Newer Toilets NSW	OSCAR	V Set	Toilet Avail/Clean	90	58%	27%	0.66	0.7%
Tram	Old v New Tram VIC	E Class	Z Class	Overall	20	77%	62%	1.34	6.7%
	Onboard Next Stop Info Display VIC	A,B	C,D,E	Information	20	74%	55%	0.36	1.8%
	Onboard Staff NSW LRT cf VIC Tram	NSW LRT	VIC Tram	Staff Avail & Helpfulness	20	82%	71%	0.52	2.6%
	Low Floor VIC	CDE Class	Z Class	Ease of On/Off	20	82%	67%	0.15	0.8%
Bus	New v Old Predicted Rating NZ	Brand New	20 Years old	Overall	23	75%	61%	1.37	5.9%
	Premium v Standard Routes NZ	AKL Loop & WEL Flyer	Standard Routes	Overall	23	79%	69%	0.95	4.1%
	Onboard Info NZ	AKL Loop & WEL Flyer	Standard Routes	Information	23	78%	54%	0.32	1.4%
	Trolley vs Diesel NZ	Trolley Bus	Average Diesel Bus	Overall	23	73%	70%	0.32	1.4%
				Environment	23	65%	60%	0.08	0.3%
	Engine Standard NZ	Euro 5	Pre Euro	Environment	23	64%	54%	0.15	0.6%
	Bus Size NZ	Std 45 seats	Midi 22 seats	Seat Av/Comf	23	75%	57%	0.38	1.6%
	Artic v Std NSW	Artic (M10)	Standard	Seating	23	76%	69%	0.11	0.5%
	Std vs Low Floor NZ	Low Floor	Std Bus	Ease of On/Off	23	77%	68%	0.14	0.6%
	Route Rating NSW	Highest	Lowest	Overall	23	85%	60%	2.39	10.4%
Ferry	Vessel Rating NSW	Fast Cat	Freshwater	Overall	30	84%	73%	2.52	8.4%
	Cleanliness	Cpt Cook Cat	Freshwater	Cleanliness	30	92%	76%	0.40	1.3%

(1) WEL Matangi v Ganz Mavag; NSW Wara v CK; NSW H v V; VIC Xtra v Comeng

The benefit of onboard train information displays was valued at 0.46 minutes based on 4 examples (2 NSW 1 NZ and 1 Victoria). The benefit for trams and buses was a little lower at 0.36 and 0.32 minutes respectively.

Air-conditioning was worth 0.55 minutes per trip based on two (NZ and NSW) comparisons.

Having onboard staff on trams was valued at 0.52 minutes by comparing the Melbourne (driver only) with Sydney LRT (staff onboard trams to issue/check tickets) in terms of the staff availability and helpfulness rating. Based on the Wellington versus Auckland train staff ratings, the value of guards with ticketing duties onboard trains was valued at 0.31 minutes.

The value of security cameras on trains was valued at 0.3 minutes by comparing the personal security rating of Waratah trains which had cameras with Tangara and CK and S sets which did not cameras when surveyed.

Wellington’s electric trolley buses were valued 0.32 minutes higher than the average diesel bus. When limited to the environmental rating (noise/emissions) the benefit fell to 0.08 minutes. A Euro 5 rated diesel bus rated 1% lower than the trolley bus in environmental rating but when compared to a pre-Euro engine standard bus, it was valued 0.15 minutes higher.

Standard sized buses were valued 0.38 minutes higher than a 22 seater midi bus. Articulated buses were also valued 0.11 minutes above standard buses based on M10 articulated buses used on Inner West services in Sydney.

8.8 Value of surface versus underground rail travel

Despite the planning and construction of new underground rail lines in Australia’s largest cities, no studies were able to be found that had attempted to estimate the passenger preference for travelling underground versus on the surface. To help fill the knowledge gap, Sydney Trains surveyed 347 Sydney rail passengers who used services where part of their trip was underground, Douglas (2016). The survey asked questions about the preference for surface versus underground travel and included a set of pair-wise Stated Preference choices to quantify any tunnel penalty. To help explain the observed preferences, respondents were asked what activities they did whilst travelling on the train.

The survey established that 46% of rail passengers preferred surface to underground travel, 39% were indifferent and 16% preferred underground travel. The most important attribute in explaining the preference for surface travel was ‘Window views’. Surface travel was also preferred, albeit less strongly, for reasons of smoothness and quietness and also safety. These three ‘intrinsic’ attributes accounted for two thirds of the overall preference for surface travel. The remaining third was explained by crowding, reliability and speed which were considered ‘route specific’ rather than ‘intrinsic’ attributes.

Using Stated Preference techniques, the survey estimated a tunnel penalty worth 1.9 minutes of rail travel time. When restricted to ‘intrinsic’ underground attributes (views, safety and smoothness and noise), the penalty reduced to 1.25 minutes. Expressed as a travel time multiplier, underground travel added 5% to travel time.

The estimated tunnel penalty, which is considered relevant for trips of 10 minutes or longer, could be used in forecasting route assignment and mode share.

8.9 De Gruyter review of vehicle amenity values

In 2018, De Gruyter, Currie, Long, Truong and Naznin undertook a meta-analysis of 57 research publications that valued public transport customer amenities, De Gruyter (2018). The work was supported by Transport for Victoria as part of a research program exploring best practice approaches to public transport customer amenity valuation.

The report,includes a ‘normalisation’ of values that expresses them in equivalent in-vehicle time. They also undertook a meta-analysis of the factors that influenced these values and reviewed the methods of valuation, the issues faced in applying the methods, and identified gaps in knowledge.

Of the 57 publications reviewed, 28 were specific valuation studies and 29 were guidelines or related research. 556 public transport customer amenity values were identified that had been estimated between 1992 and 2013. The studies were undertaken in Australia, India, New Zealand, Norway, Sweden, and United Kingdom.

The values refer to metropolitan travel as intercity values were found to be much greater and so were excluded to avoid distorting the results.

The identified amenity values were classified into six categories:

- **Access:** amenities that assist customers in travelling to, from and within station/stops and vehicles; also includes ‘accessibility’ related aspects for customers with mobility restrictions.
- **Facilities:** includes physical objects and services, e.g. ticket machines, retail outlets.
- **Information:** examples include timetables, maps, help points and directional signage.
- **Security:** amenities that support personal safety and security such as surveillance cameras, lighting and staff; also includes aspects that detract from personal safety such as graffiti.
- **Environment:** generally covers air quality, temperature control (heating/cooling), ventilation and noise related aspects of the public transport journey.
- **Condition:** physical condition/appearance such as cleanliness and presence of graffiti.

Values were also classified into (i) access/egress, (ii) waiting, (iii) boarding/alighting and (iv) in-vehicle). Values for train/metro, tram/LRT and bus were separately reported.

Table 49 presents the median (med) minimum and maximum by amenity type for boarding/alighting and in-vehicle by mode. There were few tram/light values. The train/metro values were considerably higher than bus which De Gruyter considered as reflecting longer trips. Summing the amenity values gave a median of 8.53 minutes for rail and 5.43 minutes for bus. The range was very wide however reflecting some high valuations in some studies which when summed gave a range for rail of 1.52 to 43.77 minutes and 5.33 to 54.55 minutes for bus.

Table 49: Summary of vehicle related customer amenity values – De Gruyter et al 2018

Amenity and (type)	Train/Metro			Tram/LRT			Bus		
		Range			Range			Range	
	Med	Low	High	Med	Low	High	Med	Low	High
Boarding/Alighting values by attribute									
Automatic doors (F)									
Cleanliness of vehicle exterior (S)	0.38						0.03	0.02	0.10
Décor of vehicle exterior (C)	0.38	0.15	0.40						
Graffiti on vehicle exterior (S,C)									
Handrails (A)									
Step free access to vehicle (A)	0.22	0.08	1.50	0.24			1.33	0.05	5.59
Vehicle "newness" (C)	3.34	0.78	10.61				1.57		
Boarding/Alighting values by type									
Access (A)	0.22	0.08	1.50	0.24			1.33	0.05	5.59
Security (S)	0.38						0.03	0.02	0.10
Condition (C)	0.98	0.15	10.61				0.07	0.02	1.57
Board/Alight Total	*1.58*	*0.61*	*12.49*	*0.24*	*na*	*na*	*1.43*	*0.09*	*7.26*
In-vehicle values									
Access between carriages (A)	3.72	3.04	4.39						
Ability to see between carriages (S)									
Cleanliness of vehicle interior (S,C)	0.37	0.14	9.92				1.44	0.30	9.78
Customer Alarms (S)									
Driver (attitude, helpfulness) (I,S,E)							0.51	0.02	4.91
Electronic displays/RTI (I)	0.70	0.24	6.88				0.69	0.10	11.35
Environmental Impact (E)	0.59								
Food service on-board (F)	0.09								
Gangways (A,F)									
Graffiti on interior (S,C)	3.30	0.08	6.53				0.20		
Graffiti alongside track/route (S,C)									
Hand rails (A)	0.99	0.47	1.52				0.40	0.19	0.61
Lighting (S)	0.41	0.13	0.96						
Litter (S,C)							0.72	0.40	0.84
Luggage storage (F)							0.28	0.20	0.35
Map of PT routes (I)							0.20	0.20	0.68
Multi-purpose areas in vehicle (A,F)									
Noise (E)	0.32	0.22	0.35				3.24	0.48	3.74
Odour (E)									
PA System (I,S)	1.24	0.16	3.85				1.22	0.16	9.81
Posters (I)									
Power outlets (F)									
Ride Quality (E)	1.20	0.30	4.66	0.50			0.85	0.00	4.09
Seating (F,C)	0.83	0.05	1.75				0.53	0.02	2.21
Smoothness of driving (E)	0.68	0.10	1.42	0.50			0.80	0.05	1.84
Staff (non-driver) (I,S)	1.60	0.56	3.85						
Surveillance cameras (S)	2.00	0.37	2.20				0.70	0.32	2.54
Temperature control (heating/cooling) (E)	1.50	0.15	6.79	0.39			1.00	0.55	1.24
Toilets (F)	0.60								
Ventilation (E)	1.84	0.82	2.87	0.22			0.44	0.10	0.44
Wheelchair/buggy space (F)							0.14	0.10	0.19
Wi-Fi Access (F)									
Windows (S,C)							0.35	0.30	0.39
In-vehicle values by type									
Access (A)	2.28	0.47	4.39				0.40	0.19	0.61
Facilities (F)	0.60	0.05	1.75				0.44	0.02	2.21
Information (I)	1.44	0.16	6.88				0.50	0.02	11.35
Security (S)	1.15	0.08	9.72				0.84	0.02	9.81
Environment (E)	1.01	0.10	6.79	0.45	0.22	0.50	0.64	0.00	13.43
Condition (C)	0.47	0.05	1.75				1.08	0.02	9.78
In-vehicle Total	6.95	0.91	31.28	0.45	0.22	0.50	3.90	0.27	47.19
TOTAL	8.53	1.52	43.77	0.69	na	na	5.33	0.36	54.45

A Access; C Condition: E Environment: F Facilities: I Information: S Security

9. Stop, station and wharf quality

9.1 Introduction

The approach developed for valuing vehicles can be used to value bus and tram stops, rail stations and ferry wharves. The same NZ, NSW and Victoria 2012-2014 surveys that provide the vehicles values also provided the stop, station and wharf values.

Stop quality is measured on a passenger rating scale ranging from 'very poor' to 'very good'. The ratings were converted to a percentage scale. As with vehicle quality, the approach allows for a diminishing 'willingness to pay' as stop quality improves. The approach also ensures that the values for improving individual station attributes such as seating and lighting are consistent with the values of an overall station upgrade.

A question sometimes raised by evaluators is how the values should be applied. The values are 'per passenger boarding' at the bus stop or train station. To work out the total benefit, the values should be multiplied by the number of passengers boarding at the stop or station in question. Alighting passengers and passengers making transfers may also benefit and guidance regarding this is provided in section 9.2.

It is worth mentioning that 'non-travellers' could also benefit from improved station quality. Non travelers might be 'meeters or greeters', people sheltering from the weather, using a bus stop seat for a rest or using station retail facilities. They may also be people who want to find out about public transport or buy a ticket or topping up their travel card but not travelling there and then who may also benefit from stop and station improvements.

The bus and tram surveys featured a shorter list of attributes than rail stations and ferry wharves. For bus stations, the rail station and ferry wharf values could be used for attributes that were not surveyed.

The values can be used to assess the provision of attributes and facilities at stops as well as the 'quality' of their provision. Thus the effect of providing real time information (RTI) at a bus stop can be valued by comparing the passenger rating of stops with RTI to stops without RTI. The quality of information can also be assessed via the rating scale. Thus improving information from average (50%) to good (75%) could be valued.

Section 9.3 presents a set of 'benchmark' ratings to help assess different proposals. The benchmarks are based on the 2012-14 NZ, NSW and Victoria surveys. For Wellington and Sydney, similar surveys were conducted over a longer time frame which has enabled trends in station rating and the effects of station upgrades to be assessed in more detail. Section 9.4 presents some of the findings.

9.2 Three step approach to valuing stop, station & wharf quality

The basic approach involves the same three steps outlined in section 8.2 for vehicle quality. The parameters were developed from surveying passengers about the stops where they boarded.

Alighting passengers are likely to value stop quality less and passengers transferring at stations may also have different valuations. The range in facilities provided at bus stops and train stations also has a greater range than vehicle facilities. These two issues are addressed after presenting the basic approach.

Step 1 determines the maximum value users place on overall stop quality (i.e. from very poor to very good) and measures the value in equivalent in-vehicle travel time minutes. Different values are provided for boarders, alighters and transfer passengers.

Step 2 calculates the proportion of the maximum value that an improvement represents allowing for a diminishing valuation of quality.

Step 3 multiplies the proportionate change in rating (Step 2) to the maximum value of stop quality (Step 1).

A **Step 2a** is required if individual attributes or a combination of attributes are evaluated rather than the overall stop quality 'package'. Step 2a applies a factor measuring the relative importance of attributes in determining the overall stop rating. It allows for direct and indirect or 'halo' effects.

Step 1: Determining the Maximum Stop Quality in equivalent In-vehicle time minutes

Changes in stop quality, like vehicle quality, are valued in equivalent in-vehicle time minutes. The Maximum Stop Quality (MSQ) is the difference from 0% (very poor) to 100% (very good). Table 50 gives the MSQ for bus and tram stops, rail stations and ferry wharves estimated in the 2012-14 NZ, NSW and Victoria surveys. Figure 43 plots the estimates with their 95% confidence range. The sample sizes for the estimates are presented in Table 51.

Table 50: Maximum Value of Stop, Station & Wharf Quality in Minutes

Value of Very Poor (0%) to Very Good (100%) Rating in IVT minutes

Study	Maximum Stop Valuation in IVT Minutes for Boarding Passengers					
	Bus	Tram	Light Rail	Ferry	Rail	Average
VIC	14	10	na	na	22	15
NSW	10	na	12	10	14	12
NZ	15	na	na	na	18	17
Average	13	10	12	10	18	13
Recommended Values						
Boarding Passengers	12	12	12	12	18	13
Alighting Passengers	2	2	2	6	9	4
Transfer Passengers	13	13	13	13	18	14

The estimated MSQ for bus and tram stops, Light Rail stations and ferry wharves were similar. A value of 10 minutes was estimated for Melbourne tram stops, NSW bus stops and NSW ferry wharves. A value of 12 minutes was estimated for NSW Light Rail stops, 14 minutes for Victoria bus stops and 15 minutes for NZ bus stops. Taking account their sampling accuracy, a recommended value is 12 minutes.

The MSQ for rail stations tended was greater ranging from 14 minutes for NSW to 22 minutes for Victoria. The recommended value is 18 minutes.

Table 51: Sample Sizes of Stop Quality Estimates

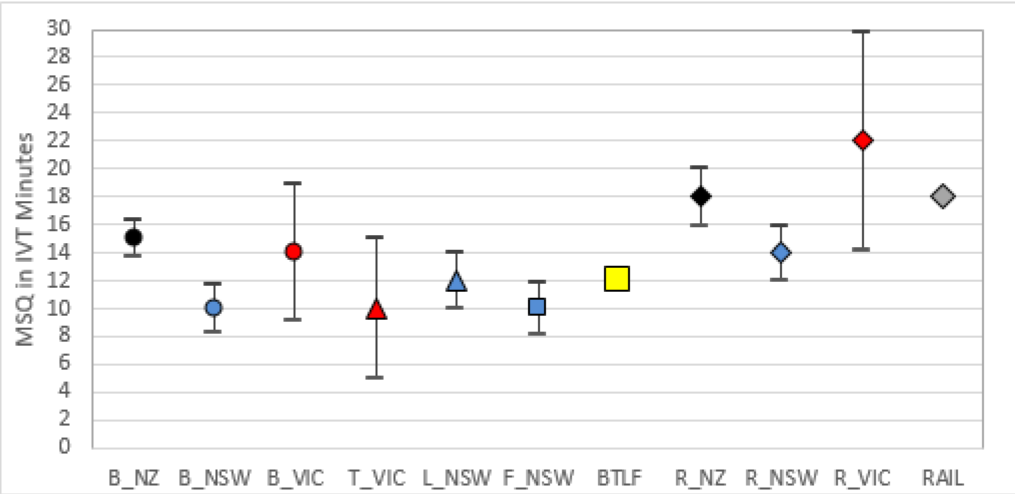
	Sample Size - Respondents					
	Bus	Tram	Light Rail	Ferry	Rail	Total
VIC	291	286	-	-	337	914
NSW	1,847	-	471	1,223	1,910	5,451
NZ	3,721	-	-	-	1,345	5,066
Total	5,859	286	471	1,223	3,592	11,431
	Sample Size - Choice Observations					
VIC	2,040	1,833	-	-	3,077	6,950
NSW	13,285	-	3,598	8,825	14,462	40,170
NZ	29,479	-	-	-	10,386	39,865
Total	44,804	1,833	3,598	8,825	27,925	86,985

The range in the NZ and NSW estimates was narrower than for Victoria estimates as can be seen from Figure 43. The ranges reflected the sample size. The NZ bus stop value of 15 minutes had a 95% confidence range of ± 1.3 minutes (|t| of 23) and was estimated on 3,721 respondents. The Sydney rail station value of 14 minutes was estimated on 1,910 respondents and had a range of ± 2 minutes. By comparison, the Victoria rail value was estimated on 339 respondents and produced a MSQ of 22 minutes with range of ± 7.8 minutes.

Figure 43 also plots the recommended values for bus, tram, Light Rail and ferry (BTLF) and for rail which were simple averages of the respective study estimates.[79]

Figure 43: Maximum Value of Stop, Station & Wharf Quality in Equivalent In-Vehicle Minutes – Boarding Passengers

Mean estimate and 95% confidence range



The MSQ values in Figure 43 are for boarding passengers. Values are also needed for alighting and transfer passengers. A set of recommended values are given in the bottom rows of Table 50.[80]

Boarders are likely to place a greater value on stop quality than alighting passengers because they

[79] Weighting the observations by their accuracy (t value) made little difference.

[80] There may also be benefit to non-PT users (pedestrians) from bus and tram stop upgrades. Lighting and seating may benefit pedestrians for example.

wait at the stop and are benefit more from information on bus and train arrivals.

Alighters however are likely to place some value on stop quality. A shelter will have value when it is raining or windy allowing bus passengers to get ready for their walk after disembarking or wait for a lift in greater comfort. Rail passengers are likely to value having escalators and lifts to ease their egress from station platforms.

Based on the relative importance of different stop / station attributes, the Sydney study calculated a set of adjustment factors for alighters. The estimates are presented in Table 54. For alighters, a factor of 15% of the boarding MSQ was calculated for bus passengers and 50% for rail and ferry passengers. For rail passengers transferring between trains at stations, the same MSQ value as for boarding passengers was calculated. In Table 54, these percentages were multiplied by the recommended boarding MSQ values to produce the alighting and transfer values.

Step 2: Transforming the Stop Quality Ratings to Valuation Ratings

Step 2 calculates the proportion of maximum value of stop quality (MSQ). As with vehicle quality, it is highly unlikely that the maximum value will apply. The proportion also needs to be transformed to take account of a diminishing value for improved stop quality. Step 2 therefore transforms the rating scale using a power function. A value of 0.7 for the power function, the same as for vehicle quality is recommended (see equation 8.2) based on analysis of the survey data.

Step 3: Multiply the maximum value of stop quality with the transformed change in rating

The maximum value of stop quality (MSQ) calculated in Step 1 is multiplied by the change in the transformed rating (ΔRt) in Step 2 to value of the improvement in equivalent in-vehicle time minutes.

As for vehicle quality, a 0% to 100% ‘real-life’ change in stop quality is virtually impossible. A reasonably range is 40% to 80%.

If a rail station upgrade managed to achieve this increase, the improvement would be worth 5.9 minutes in equivalent in-vehicle time (of 18 minutes).

$\Delta IVT = MSQ \times \Delta Rt = 18 \times 033 = 5.9$ IVT minutes …..(9.1)

For alighting passengers, the benefit would be 3 minutes (33% of 9 minutes).

The rail value is similar to the median value of 5.4 minutes derived from the NZ literature review.[81] The De Gruyter international review value was lower at 2.8 minutes.

The bus value of 4.3 minutes is lower than the NZ review estimate of 6 minutes but close to the De Gruyter value of 4.6 minutes. The wharf value of 3.3 minutes is higher than the figure of 1.5 minutes estimated in a 2002 study of Sydney ferries by Booz. As with vehicle quality, comparisons are difficult because of the varying lists of attributes considered and how they were described and measured. None of the studies provided values for alighting passengers.

[81] Median values have been reported from the literature review for bus and rail because of the effect of two studies that produced high estimates. The mean values were 7.4 minutes for bus and 13.1 minutes for rail.

Table 52: Comparison of Estimated Value of Stop Quality with Literature Review Estimates

Estimate	Bus	Tram	Light Rail	Ferry	B,T,L,F	Rail
Rating	4.3	3.3	3.9	3.3	3.9	5.9
Literature Review (2)	6.0	-	-	1.5	-	5.4
De Gruyter	4.6	-	-	-	-	2.8

B.T,L,F = recommended value for bus, tram, Light Rail and ferry (1) Studies 2,8, 12-14, 41, 43-46 and 19 for ferries. De Gruyter (2018) international review – sum of access/egress and waiting values.

9.3 Valuing Changes in the Quality of Stop Attributes

When changes to individual stop attributes or combinations of attributes need to be evaluated an additional step (2a) is needed which takes account of their relative importance.

Table 53 presents the relative importance of stop, station and wharf attributes based on analysis of NZ, Victoria and NSW surveys.[82] There were differences in the list of attributes surveyed. A shorter list was used for bus, tram stops and Light Rail stations than rail stations and ferry wharfs.

Table 53: Relative Importance (% of Total) of stop, station and wharf attributes

	Bus				Tram	LRT	AV	Ferry	Rail			
Attribute	NZ	VIC	NSW	AV	VIC	NSW		NSW	NZ	VIC	NSW	AV
Weather Protection	23%	27%	26%	25%	24%	12%	18%	16%	13%	13%	6%	10%
Seating	23%	21%	17%	20%	20%	14%	17%	13%	11%	11%	7%	9%
Timetable	18%	22%	23%	21%	21%	17%	19%	9%	9%	9%	11%	9%
Lighting	10%	15%	9%	11%	14%	13%	14%	3%	7%	7%	6%	6%
Cleanliness & Graffiti	26%	15%	25%	22%	14%	31%	23%	17%	18%	17%	16%	15%
Ticket Purchase	-	-	-	-	7%	13%	10%	3%	8%	8%	6%	7%
Platform Surface	-	-	-	-	-	-	-	-	9%	9%	5%	7%
Platform Access	-	-	-	-	-	-	-	-	9%	9%	6%	7%
On/Off Ferry	-	-	-	-	-	-	-	20%	-	-	-	-
Toilet Avail/Clean	-	-	-	-	-	-	-	2%	1%	2%	3%	2%
Staff Avail/Helpful	-	-	-	-	-	-	-	6%	2%	2%	6%	3%
Retail/Food/Drinks	-	-	-	-	-	-	-	3%	4%	4%	3%	3%
Car Parking & Pick Up	-	-	-	-	-	-	-	1%	7%	8%	5%	6%
Taxi drop off	-	-	-	-	-	-	-	-	-	-	0.3%	0.3%
Ease of Bus Transfer	-	-	-	-	-	-	-	7%	1%	1%	1.4%	1%
Bicycle facilities	-	-	-	-	-	-	-	-	-	-	0.5%	0.5%
Design and Layout	-	-	-	-	-	-	-	-	-	-	6%	5%
Signage	-	-	-	-	-	-	-	-	-	-	5%	5%
Personal Security	-	-	-	-	-	-	-	-	-	-	3%	3%
Station telephones	-	-	-	-	-	-	-	-	-	-	2%	2%
Sample	3,479	256	1,733	5,468	257	781	1,038	1,334	8,713	308	6,813	15,834

[82] The rail sample sizes were increased by including similar surveys done before 2012.

The bus stop profiles were similar with weather protection, seating, information and cleanliness explaining a fifth to a quarter of total importance. Lighting was around 10%. For tram and LRT stops, ease of ticket purchase accounted for 10% which reduced the importance of the other attributes. The surveys were undertaken between 2012 and 2014 and since then integrated ticket use has grown which may have reduced the importance of ticket purchase.

For ferry, ease of boarding and alighting was the most important wharf attribute at 20% followed by cleanliness and graffiti (17%) and weather protection (16%).

The Sydney rail station survey covered twenty attributes which dampened the effect of each attribute. However, the larger MSQ (18 versus 12 minutes) means the value of improving ‘common’ attributes is similar.

Only cleanliness / graffiti and information accounted for more than 10%. The importance of weather protection dropped to 6%.

Access facilities other than car parking and drop off (i.e. bus transfer, bicycle racks and storage, taxi drop off) had relatively low importance which reflected their access trip share.[83] Only for ferry was ease of bus transfer important at 7%.

The Sydney study determined the likely importance of attributes for alighting and transfer passengers. Table 54 presents the estimates. For alighting passengers (ALT), importance was determined by applying an assumed factor (*FAC*) to the importance share for boarders (BRD). Thus for bus stop weather protection, the board importance of 26% was multiplied a factor of 20% to get an attribute importance of 5.2% for alighting passengers. For rail transfers, attribute importance was directly estimated from respondents who had transferred trains at the surveyed station.

The sum of the attributes gave a factor which was applied to the maximum stop quality (MSQ) value for boarders in Table 54. The factor was 15% for bus, 50% for ferry and rail and 100% for rail transfer passengers. It should be noted that the MSQ value for alighters should not then be applied to the alight importance shares as this would underestimate the value of an attribute improvement. If the attribute importance shares for alighters are used, then they should be applied to the MSQ for boarders.

The direct effect of a change in stop attribute rating or a combination of attributes is modelled in the same way as for vehicles using equation 8.5.

The change in attribute rating (ΔAi) is multiplied by its direct importance (Di) to determine the change in overall rating (ΔR). This is added to the base overall stop rating (R1) to get the new overall stop rating (R2).

The base and overall stop ratings are then transformed using the power function (equation 8.2)

As an example, a proposal to replace the seats at a stop with an overall rating of 50% needs evaluation. The new seats are expected to improve the seat rating by 40% points. From Table 54, the importance of seating is 17%. Multiplying the respective rating increases by their importance shares gives a predicted increase in the overall bus stop rating of 6.8%.

83 In estimation, importance was modelled by multiplying by a dummy variable (1,0) according to whether the respondent used the respective access mode or not.

Table 54: Attribute Importance for Alighting and Transfer Passengers – Sydney Study

Attribute	Bus			Ferry			Rail			
	BRD	*FAC*	ALT	BRD	*FAC*	ALT	BRD	*FAC*	ALT	TRF
Weather Protection	26%	*20%*	5.2%	16%	*20%*	3.2%	6.1%	*20%*	1.2%	6%
Seating	17%	*10%*	1.7%	13%	*20%*	2.6%	7.1%	*20%*	1.4%	5%
Timetable Info & Announcements	23%	*20%*	4.6%	9%	*25%*	2.3%	11.2%	*25%*	2.8%	14%
Lighting	9%	*25%*	2.3%	3%	*50%*	1.5%	6.1%	*50%*	3.1%	6%
Cleanliness & Graffiti	25%	*5%*	1.3%	17%	*50%*	8.5%	16.3%	*50%*	8.2%	16%
Ticket Purchase				3%	*0%*	0.0%	6.1%	*0%*	0.0%	3%
Platform Surface & Appearance							5.1%	*20%*	1.0%	4%
Ease of getting to/from platform							6.1%	*100%*	6.1%	9%
Ease of getting on/off train/ferry				20%	*100%*	20.0%	5.1%	*100%*	5.1%	6%
Toilet Availability & Cleanliness				2%	*100%*	2.0%	3.1%	*100%*	3.1%	2%
Staff Availability & Helpfulness				6%	*25%*	1.5%	6.1%	*25%*	1.5%	7%
Ability to Buy Food, Drinks, Paper				3%	*50%*	1.5%	3.1%	*50%*	1.6%	6%
Car Parking & Pick Up * Car %				1%	*100%*	1.0%	5.1%	*100%*	5.1%	0%
Taxi drop off * Taxi %							0.3%	*100%*	0.3%	0%
Ease of Bus Transfer * Bus %				7%	*100%*	7.0%	1.4%	*100%*	1.4%	0%
Bicycle facilities * Bike %							0.5%	*100%*	0.5%	0%
Design and Layout							6.1%	*100%*	6.1%	6%
Signage							5.1%	*25%*	1.3%	5%
Personal Security							3.1%	*100%*	3.1%	3%
Station telephones							2.0%	*100%*	2.0%	2%
Total	100%	*na*	15%	100%	*na*	51%	100%	*na*	50%	100%

Applying the power transformation to the base (50%) and new (56.8%) overall ratings gives a transformed difference of 5.7% points. For passengers boarding at the stop, the improvement would be worth 5.7% of the MSQ value. Using the recommended value of 12 minutes in Table 50 gives a benefit of 0.69 IVT minutes. There would also be a small benefit to alighting passengers of 0.11 IVT minutes (2 x 0.057).

As for the vehicle attribute ratings, correlations between stop attribute ratings suggested halo effects should be taken into account whereby improving the rating of one stop attribute by raising the ratings of other stop attributes, increases the overall stop rating.

Table 55 sets out the estimated direct and halo effects for Sydney bus stops, train stations and ferry wharves.[84]

The sum of halo effects need not sum to 100%. In Table 55 the sum ranges from 0.73 for ferry to 1.004 for rail boarders.

Inclusion of the halo effect is the same as for vehicles and involves multiplying the change in attribute rating (ΔAi) by the sum of the direct importance (Di) plus the halo importance (Hi) as was

[84] Halo effects were not estimated for Sydney LRT or the Melbourne and NZ data.

shown in equation 8.6. This gives the predicted change in the overall rating (ΔR). The result is then added to the base overall rating (R1) to get the new overall rating (R2). The base and new stop ratings then need to be transformed using the power function (equation 8.1).

Table 55: Direct and Halo Effects for Stop, Station and Wharf Attributes – Sydney Rating Data

	Bus Stop		Ferry Wharf		Rail Station					
	Boarders		Boarders		Boarders		Transfers		Alighters	
Attribute	Direct	Halo	Direct	Halo	Direct	Halo	Direct	Halo	Direct	Halo
Weather Protection	0.26	0.13	0.16	0.06	0.061	0.05	0.060	0.050	0.012	0.023
Seating	0.17	0.22	0.13	0.12	0.071	0.046	0.050	0.040	0.014	0.017
Timetable Info & Announcements	0.25	0.1	0.09	0.07	0.112	0.111	0.140	0.122	0.028	0.039
Lighting	0.09	0.16	0.03	0.09	0.061	0.094	0.060	0.102	0.031	0.046
Cleanliness & Graffiti	0.23	0.12	0.17	0.08	0.163	0.071	0.160	0.067	0.082	0.035
Ticket Purchase	-	-	0.03	0.05	0.061	0.106	0.030	0.081	-	-
Platform Surface & Appearance	-	-	-	-	0.051	0.111	0.040	0.103	0.010	0.056
Ease of getting to/from platform	-	-	-	-	0.061	0.053	0.090	0.054	0.061	0.030
Ease of getting on/off train/ferry	-	-	0.2	0.09	0.051	0.036	0.060	0.034	0.051	0.011
Toilet Availability & Cleanliness	-	-	0.02	0.03	0.031	0.04	0.020	0.040	0.031	0.022
Staff Availability & Helpfulness	-	-	0.06	0.12	0.061	0.049	0.070	0.045	0.015	0.024
Ability to Buy Food, Drinks, Paper	-	-	0.03	0.05	0.031	0.031	0.060	0.025	0.016	0.013
Car Parking & Pick Up	-	-	0.01	0.03	0.051	0.023	-	-	0.051	0.013
Taxi drop off	-	-	-	-	0.003	0.004	-	-	0.003	0.004
Ease of Bus Transfer	-	-	0.07	0.02	0.014	0.015	-	-	0.014	0.012
Bicycle facilities	-	-	-	-	0.005	0.013	-	-	0.005	0.012
Design and Layout	-	-	-	-	0.061	0.052	0.060	0.060	0.061	0.033
Signage	-	-	-	-	0.051	0.057	0.050	0.067	0.013	0.031
Personal Security	-	-	-	-	0.031	0.024	0.030	0.024	0.031	0.015
Station telephones	-	-	-	-	0.02	0.018	0.020	0.023	0.020	0.007
Total	1	0.73	1	0.81	1	1.004	1	0.937	0.5	0.443

Returning to the 40% improvement in bus stop seat rating at a bus stop with a base rating of 50%. From Table 55, the halo effect is 22%. The halo effect is added to the direct effect (importance share) of 17% to get 39%. Multiplying the 40% improvement by 39% gives an increase in the overall stop rating of 15.6%. Applying the power transformation to the base overall rating of 50% and the new predicted rating of 65.6% gives a transformed difference of 12.9%. The value of the improvement is worth 1.55 minutes of IVT which is slightly more than double the direct benefit of 0.69 minutes.

For improvement packages of more than one attribute, the method shown for vehicles can be used which will reduces the halo effect as more attributes are added.

9.4 Variation in Stop, Station & Wharf Ratings

The NZ, NSW and Victoria surveys provided passenger ratings for individual rail stations (including Light Rail stops in Sydney) and individual ferry wharves. Ratings for bus stops and Melbourne tram stops were aggregated either because of imprecise locations or because response was too small. Table 56 describes the data.

Table 56: Details of Stop, Station and Wharf Surveys

Loc	Mode	Description	N	Sample
NZ	Bus	Aggregated bus stops in Auckland, Christchurch and Wellington.	75	3,479
NZ	Rail	Responses from 39 Auckland stations (out of 42) and 48 Wellington stations. Response was also grouped into hub, major and local stations. Additional survey data from an earlier 2002/3 survey was used in a comparative analysis of station upgrading.	87	8,713
VIC	Bus	Study was orientated to valuing passenger information. Stops and ratings were grouped into CBD, inner suburb and outer suburbs. Bus stops were analysed according to attribute availability as judged by passengers	3	600
VIC	Tram	As for VIC bus stops. Tram stops were also analysed by street section to compare passenger versus actual provision of attributes.	3	637
VIC	Rail	As for VIC bus stops.	3	1,488
NSW	Bus	306 bus services were surveyed on 90 Sydney, Newcastle and Wollongong bus routes. 66 routes had a sample size above 20. Bus routes were aggregate into 8 segments. Inner West bus stops were aggregated into 14 street sections.	90	3,646
NSW	LRT	Surveyed the 14 stops on the Central to Lilyfield service stations (including Central).	14	1,278
NSW	Ferry	Surveyed Sydney harbour, Parramatta River and the Newcastle-Stockton service	33	2,557
NSW	Rail	Station rating surveys were undertaken at intervals from 2004 to 2014 providing ratings for 114 stations with at least 10 responses. The data was split into 2004-08 (3,283) and 2009-14 (6,279) with only the 2009-14 responses (68 stations) used in the rating variation (Table 57).	68	6,279
Total			376	28,677

Table 57 summarises the passenger ratings. The average rating is the unweighted average of the NZ, Sydney and Melbourne estimates. The maximum and minimums provide a guide to the maximum change in rating that could be expected for an improvement.

The overall average rating was 68%. Bus stops rated the lowest on 64% then rail stations on 66%. Tram/LRT stops averaging 68% with Sydney ferry wharves the highest rated on 74%. The range in the average rating across the four modes was 10% points (64% to 74%).

There was a naturally a much wider range in the minimum and maximum ratings. The widest was for rail which ranged from 25% for Ava station in Wellington to 88% for Macquarie Park station in Sydney which had just been opened when surveyed. Averaging across the 4 modes gave a quality range of 40% to 83% which supports the recommended practical maximum of 40-80%.

Table 57: Stop, station and wharf ratings – NZ, Sydney and Melbourne (2009-2014)

Attribute	Average Rating					Bus		Tram/LRT		Ferry		Rail		Average	
	Bus	TrmL	Ferry	Rail	All	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Weather Protection	58%	64%	74%	65%	65%	13%	79%	40%	84%	64%	78%	33%	92%	38%	83%
Seating	58%	61%	68%	54%	60%	37%	76%	46%	75%	61%	75%	23%	78%	42%	76%
Information	65%	64%	73%	66%	67%	39%	84%	38%	75%	70%	75%	37%	85%	46%	80%
Lighting	65%	63%	76%	67%	68%	29%	78%	41%	82%	71%	79%	38%	92%	45%	83%
Cleanliness & Graffiti	63%	69%	78%	65%	69%	44%	86%	56%	91%	72%	82%	30%	90%	51%	87%
Ease of Ticket Purchase	na	53%	72%	63%	63%	na	na	20%	83%	44%	83%	9%	81%	24%	82%
Platform Surface	na	na	na	66%	66%	na	na	na	na	na	na	45%	87%	45%	87%
Platform Access	na	na	na	65%	65%	na	na	na	na	na	na	28%	87%	28%	87%
Ease of On/Off	na	na	81%	73%	77%	na	na	na	na	82%	84%	40%	85%	61%	85%
Toilet Avail/Clean	na	na	56%	45%	51%	na	na	na	na	44%	63%	4%	81%	24%	72%
Staff Avail/Helpfulness	na	na	74%	60%	67%	na	na	na	na	57%	78%	14%	83%	36%	81%
Retail/Food Drink	na	na	60%	53%	57%	na	na	na	na	25%	81%	3%	75%	14%	78%
Car Park/Pick Up	na	na	57%	56%	57%	na	na	na	na	48%	79%	27%	81%	38%	80%
Taxi drop off	na	na	na	57%	57%	na	na	na	na	na	na	34%	77%	34%	77%
Bus Transfer	na	na	73%	63%	68%	na	na	na	na	63%	79%	13%	78%	38%	79%
Bicycle Facilities	na	na	na	51%	51%	na	na	na	na	na	na	33%	83%	33%	83%
Design & Layout	na	na	na	65%	65%	na	na	na	na	na	na	41%	84%	41%	84%
Signage	na	na	na	66%	66%	na	na	na	na	na	na	46%	82%	46%	82%
Personal Security	na	na	na	64%	64%	na	na	na	na	na	na	40%	84%	40%	84%
Station telephones	na	na	na	58%	58%	na	na	na	na	na	na	43%	43%	43%	43%
Overall Rating	64%	68%	74%	66%	68%	46%	80%	36%	81%	54%	84%	25%	88%	40%	83%

'Ease of getting on and off the platform' was the highest attribute averaging 77%. Toilet availability and cleanliness and bicycle storage facilities were the lowest rated attributes (51%).

Seating (availability and comfort) rated the lowest (60%) of the five common attributes and cleanliness and graffiti was the highest rated (69%).

In terms of range, the lowest minimum rating for bus stops was weather protection (13%). For rail, weather protection achieved the highest rating (92%) and unsurprisingly it was for a new underground rail station, Macquarie Park.

Figure 44 provides some photographs illustrating the range in passenger ratings of the bus stops and train stations surveyed in the 2012-14 New Zealand survey. Bus stations on the Auckland Northern Expressway achieved the highest ratings (80%). Bus stops without shelter and seating scored 40%. Newmarket station in Auckland which had been upgraded in 2010 scored 79% and Ava in Lower Hutt (Wellington) rated the lowest on 25%.

Figure 44: Range in NZ bus stop and rail station ratings

NZ Bus Stop Rating Range

Bus stations on Auckland Northern Express Busway scored the highest ratings of 80%.

Bus stops like this one in Wellington had no shelter or seating and scored 46%.

NZ Rail Station Range

Newmarket station in Auckland which had been recently upgraded (2010) was the highest rated station in NZ scoring 79%.

Ava station in Lowe Hutt suffered from repeated graffiti attacks when surveyed. It was the lowest rated station in NZ at 25%

Figure 45 presents the top and bottom five rated NSW rail stations surveyed in 2009-14. Macquarie Park and Macquarie Uni which opened in 2009 and were surveyed soon afterwards were the top rated stations scoring 88% and 85% respectively. Punchbowl on the Bankstown Line was the worst rated station on 44%.

Figure 46 ranks bus, tram/LRT stop and train stations in terms of their overall rating. The bus stop and train station ratings were taken from the NZ survey; the LRT ratings from the Sydney Central-Lilyfield survey and the tram stop ratings from the Victoria survey. Bus 'stops' were classified into bus station, city centre and suburban stops; tram stops into city centre and suburban and train stations into hub, major and local stations.

Figure 47 shows the range in Sydney ferry wharf ratings. Ratings ranged from 84% for Milsons Point down to 48% at Darling Point. Manly and Circular Quay, the two largest wharfs rated at 76% and 73%. Queens Wharf and Stockton Wharf on the Hunter River Newcastle ferry averaged 75%.

Figure 45: Top & Bottom Ranked Rail Stations in 2009-14 NSW Survey

Top 5		Bottom 5	
1. Macaquarie Park Opened 2009 Epping Chatswood Rail Line Underground platform Passenger Rating 88%		**88. Flemington** At present site since 1924. Main West, 14kms from Central. No Lifts. Passenger Rating 50%	
2. Macaquarie Uni Opened 2009 Epping Chatswood Rail Line Underground platform Passenger Rating 85%		**89. Kingswood** Opened 1887, Main West 53 kms from Central. No Lifts Passenger Rating 49%	
3. Green Square Opened 2000 Airport Rail Line. Underground. Passenger rating 83%		**90. Rooty Hill** Opened 1861 rebuilt 1940s. Main West 41kms from Central. No lifts. Passenger Rating 49%	
4. Woolooware Rebuilt 2010 as part of Caringbah-Cronulla duplicaton. Has lifts. Passenger Rating 83%		**91. Macdonaldtown** Rebuilt 1892. On Main West 2.5kms from Central. No lifts Passenger Rating 48%	
5. Goulburn Opened 1869. Southern Highlands / intercity services Passenger Rating 81%		**92. Punchbowl** Opened 1909. Bankstown line 16.5kms from Central No lifts. Passenger Rating 44%	

Figure 46: Ranking of bus, tram/LRT stop and train stations - NZ, Sydney and Melbourne data

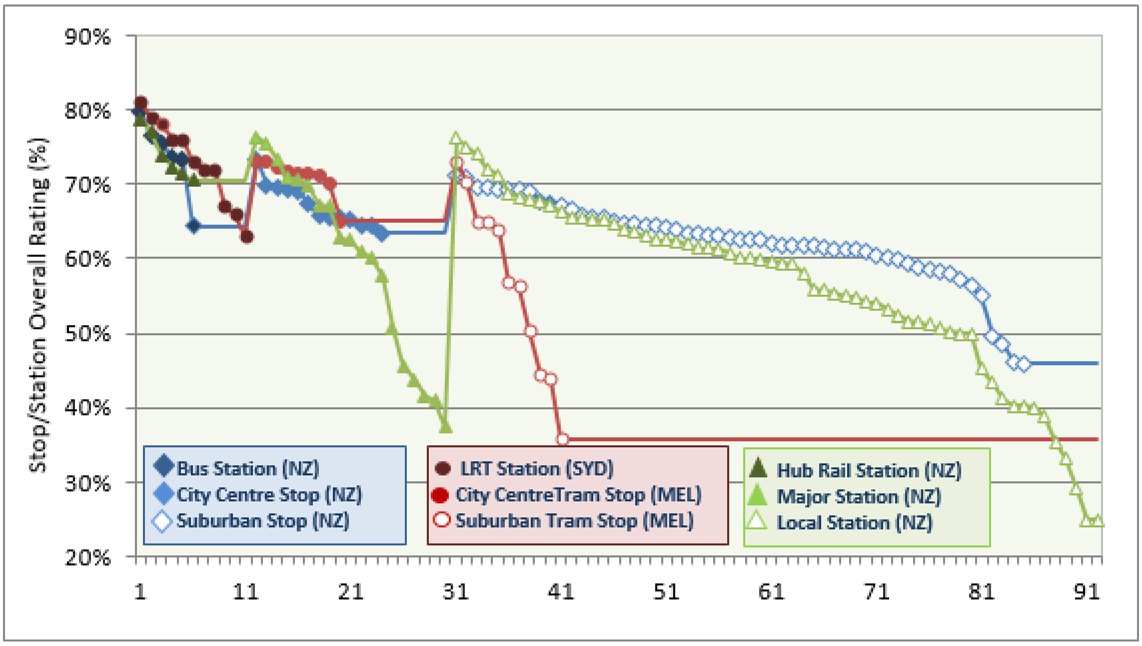
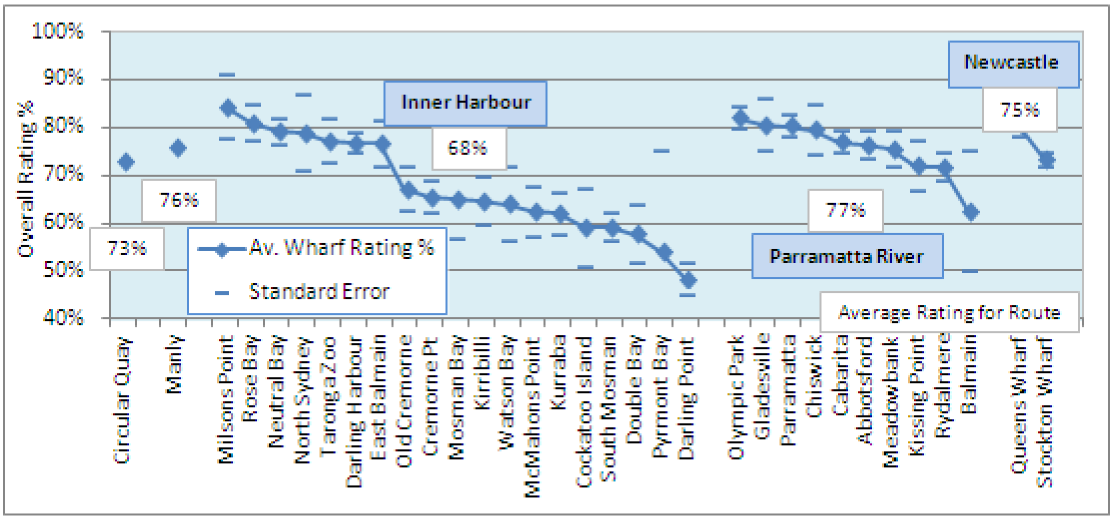


Figure 47: NSW Wharf Ratings by Ferry Route



standard error was ±1% for Circular Quay and Manly

Table 58 presents a summary of ratings by type. Bus stations, LRT stations, hub rail stations and the two main ferry wharfs (Circular Quay and Manly) achieved ratings of 73 to 74% reflecting their high level of facility provision and operational quality.

The NZ bus station ratings ranged from a high of 80% for the Albany Northern Expressway station to 64% for the bus stop at Wellington Airport. The six NZ hub rail stations ranged from 79% at Newmarket down to 71% at Porirua.

Melbourne city centre tram stops averaged 71% which was 4% points higher than NZ city centre bus stops (67%) and major NZ rail stations (60%). However, as was shown in Figure 46 the station ratings overlapped.

Suburban NZ bus stops rated at 62% compared to suburban Melbourne tram stops on 57% and NZ local rail stations on 56%. The range in ratings was widest for these stops and stations.

Ratings for the wharfs other than Circular Quay and Manly rated at 71% with a range from 84% down to 48%.

Table 58: Rating of stops, station and wharfs by type

Bus (NZ)		Tram (VIC) & LRT (NSW)		Rail Station (NZ)		Ferry Wharf (NSW)	
Type	Mean (Range)	Type	Mean (Range)	Type	Mean (Range)	Type	Mean (Range)
STA	74% (64%-80%)	LRT	73% (63%-81%)	Hub	74% (71% - 79%)	CM	74% (73%-76%)
CC	67% (63%-73%)	CC	71% (65% - 73%)	MAJ	60% (38% - 76%)	OTH	71% (48%-84%)
SUB	62% (46%-71%)	SUB	57% (36% - 73%)	LOC	56% (25% - 76%)		

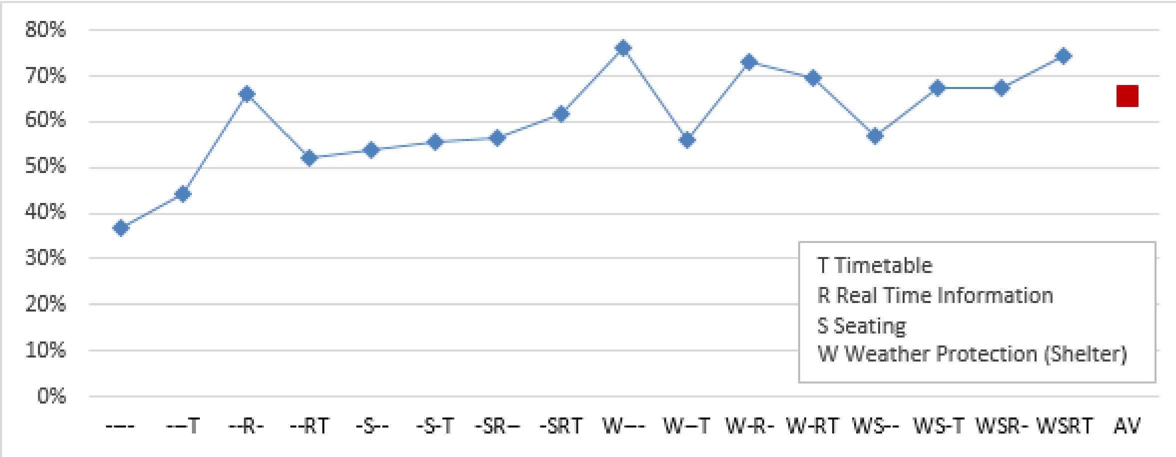
STA Bus station; CC City Centre; SUB Suburban; MAJ Major; LOC Local;
CM Circular Quay & Manly; OTH Other

9.5 Valuing bus and tram stop attribute provision

A value for attribute provision at bus and tram stops was estimated based on passenger perceptions i.e. what attributes they thought were provided. Perception may not accord with reality i.e. what was actually provided.

To produce the values, bus and tram passengers in the NZ, NSW and VIC surveys were asked whether a timetable (T); electronic real time information (R); seating (S) and shelter (W) were provided at their stop. Figure 48 graphs the overall stop rating for the 16 combinations of timetable (T), Real Time Information (R) seating (S) and weather protection (W) provision. Total response was 5,157. There was response for all 16 combinations.[85] Sample size varied from 8 respondents for weather protection and real time information (RTI) to 1,935 for the full combination.

Figure 48: Overall Stop Rating with attribute provision



	----	---T	--R-	--RT	-S--	-S-T	-SR--	-SRT	W---	W--T	W-R-	W-RT	WS--	WS-T	WSR-	WSRT	AV
Rating	37%	44%	66%	52%	54%	56%	56%	62%	76%	56%	73%	70%	57%	67%	67%	74%	66%
Sample	171	284	24	94	46	383	25	167	32	124	8	47	149	1598	80	1935	5167

Tram passengers were also asked whether their stop was a raised platform and whether Myki ticket purchase and top up facilities were available.

Table 59 presents the average overall stop rating with and without attribute provision and the value of provision in IVT minutes calculated using the 3 step method and a maximum stop quality value of 12 minutes.[86] For bus, the sum of the individual attribute values was less than the provision of all attributes. An adjustment factor was therefore calculated of 13% which scaled the values up to the all attribute value.[87]

The provision of shelter was valued highest at 1.58 minutes of IVT for boarding bus and tram passengers. RTI was valued at 1.01 minutes. A basic timetable was worth 0.91 minutes. Seating had a low value of 0.27 minutes implying that most passengers are happy to stand whilst waiting.

For the two additional tram attributes, a combinatory analysis was not possible because of the much smaller sample size (286). Due to the correlations in attribute provision, a downwards adjustment was necessary to the 'direct' estimates which gave a value of 0.46 minutes for raised

[85] Response therefore provided a full factorial experimental design with zero correlation between attributes (unweighted response).

[86] For timetable, the estimates were 61% and 60% which was considered unrealistic reflecting respondent confusion (nearly all stops should have some timetable information). Instead, the 'no provision' rating was based on the zero attribute rating (37%) and the provision attribute was based on the timetable only provision (44%).

[87] The adjustment factor is akin to a halo effect.

tram platforms and 0.35 minutes for at stop Myki ticketing purchase/top-up facilities.[88]

Table 59: Value of the provision of bus stop and tram attributes for boarding passengers

Attribute	Provision		Overall Rating		Value IVT mins	
	No	Yes	ΔR	ΔRt	Direct	Total
Timetable	37%	44%	7%	7%	0.81	0.91
RTI	56%	65%	9%	7%	0.90	1.01
Seating	59%	62%	2%	2%	0.24	0.27
Shelter	53%	68%	14%	12%	1.39	1.58
ALL	37%	74%	37%	32%	3.78	3.78
Raised Tram Platform	47%	69%	22%	18%	2.18	0.46
Tram Myki Ticket Facilities	53%	70%	17%	14%	1.65	0.35
Tram All Facilities	29%	73%	44%	38%	4.58	5.20

Total for bus = individual facility multiplied by All attributes ÷ sum of individual attributes

For tram - calculated as the share of the difference in 'tram all facilities' - 'All facilities'

9.6 Valuing rail station attribute provision

A comparison of station ratings ‘with and without’ various attributes was undertaken. Unlike bus and trams stops, facility provision was based on ‘actual’ provision. A problem in estimating the values was in controlling for other factors influencing the rating. Table 60 presents the valuations expressed in in-vehicle time minutes for boarding passengers.[89]

An aim of the Victoria study was to value electronic passenger information displays (PIDs) at rail stations which provide real time information on train arrivals. Stations with PIDs scored an overall rating of 67% compared to 58% at stations without PIDs. However, PIDs stations were also more likely to have other facilities than non PID stations. Referencing the bus and tram results reduced the ‘with’ rating to 62%. Using the 3 step method, the 5% rating difference transformed to 3.3% and was worth 0.59 IVT minutes when multiplied with the maximum station quality (MSQ) value of 18 minutes.

The estimated benefit for providing other attributes was based on the NZ and NSW surveys. They were calculated using step 2a in the 3 step approach (and included indirect ‘halo’ effects).

Having staff at NZ stations was worth 0.52 minutes. Ticketing facilities were worth 0.36 minutes at Wellington stations. Toilets and retail facilities were worth around 0.3 minutes each.

The provision of car parking, bus transfer, bicycle racks and taxi ranks had low valuations which reflected small increases in attribute rating with provision and low attribute importance.

[88] It was not possible to do a similar ‘combinatory’ analysis. Comparing the ‘with’ and ‘without’ ratings produced too high a value because of a positive correlation with other attribute provision. An adjustment was made that constrained the value of the two additional attributes to the difference in the tram ‘all attribute provision’ minus the ‘bus + tram’ ‘all attribute provision’ which was 0.8 minutes.

[89] To be consistent, the valuations applied the parameters in Table 53, Table 54 and Table 55 to the difference in passenger rating rather than the specific parameters in the NZ, Sydney and Melbourne studies.

Table 60: Value of selected rail station attribute provision measured in IVT minutes per boarding trip

Attribute	Value Mins	Survey	Comment
Passenger Information Displays (PIDs)	0.59	VIC	Comparison of stations with/without PIDs (adjusted for more facilities at PIDs stations) for suburban trains.
Ticket Purchase Facilities	0.36	NZ	Calculated on difference in ticket rating at Wellington stations with/without ticket purchase facilities of 14% points.
Staff Presence	0.52	NZ	Calculated on difference in staff rating at stations with/without staff of 32% applied to overall rating for stations without staff of 56%.
Retail Facilities	0.30	NZ	Calculated on difference in retail rating for stations with/without of 32% applied to overall rating for stations without retail of 56%.
Toilets	0.31	NZ	Calculated on difference in rating of stations with/without toilets of 32% applied to overall rating for stations without toilets of 55%.
Provision of Lifts	0.60	NSW	Calculated on difference in platform access rating for stations with stairs with/without lifts of 36% applied to overall station rating of 60%.
Ease of Bus Access	0.03	NZ	Calculated on difference in bus transfer rating for stations with/without of bus transfer of 32% applied to overall rating for stations without bus access of 56%.
Car Park / Drop Off	0.05	NSW	Calculated on difference in car park rating at stations with/without car parking of 9% applied to overall station rating for 60%.
Bike Racks/Lockers	0.01	NSW	calculated on difference in bike rating with/without bike rack/locker of 4% applied to overall station rating of 60%.
Taxi Rank	0.01	NSW	Calculated on difference in taxi rating at stations with/without taxi rank of 32% applied to overall station rating of 60%.

Providing lifts at stations where there were only stairs to/from platforms (i.e. no escalators or ramps) produced a benefit of 0.6 minutes. The benefit was based on ratings surveys undertaken in NSW. During the 2000s, an 'easy access' program introduced passenger lifts through the Sydney rail system. The main aim was to improve access for wheelchair and other mobility challenged users. Surveys undertaken by RailCorp estimated the use of rail by mobility challenged (MC) and non MC passengers at stations with and without lifts and benefit from introducing lifts. Table 61 shows that lifts increased mobility challenged use of rail by 65%. Most was by passengers with pram/strollers and by old and/or infirm passengers. Nevertheless, wheelchair passengers only accounted for 1 in 1,024 rail users where there were lifts. Wheelchair passengers were not observed at the stations without lifts. The user benefit from lifts was estimated at 0.1 minutes ranging from 3.19 minutes for wheelchair passengers to only 0.01 minutes for non-MC users. The average benefit was 0.1 minutes which was only 1/6th of the rating based estimate of 0.6 minutes.

Table 61: Value of passenger lifts at rail station by passenger mobility status

Estimate	Wheel-chair	Pram/ Stroller	Bike	Heavy luggage	Old/ Infirm	Total MC	Non MC	All
Station Trips without Lifts	0	8	4	10	13	35	965	1,000
Station Trips with Lifts	1	13	5	14	26	59	965	1,024
Benefit (without profile) mins						1.9		0.08
Benefit (with profile) mins	3.19	1.98	1.14	1.55	2.39	2.0	0.01	0.13
Benefit (average) mins						2.0		0.10

Source: "Estimating the User Benefit of Rail Station Lifts" Douglas (2012)

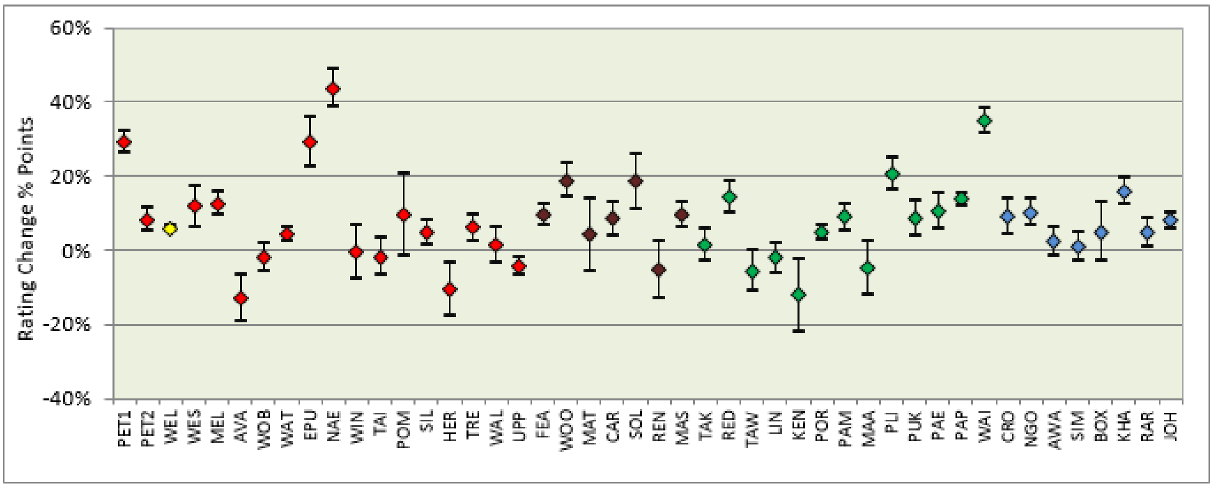
9.7 Valuing rail station upgrades - Wellington

Wellington and NSW have undertaken ratings surveys of rail stations for a decade or more and in doing so have been able to track the change in rating for individual stations and assess the effect of new stations and station upgrading. This section summarises the Wellington research and section 9.8 the NSW work.

For Wellington a 2012-13 station rating survey was compared with a near identical survey undertaken a decade previously in 2002-04. Both surveys had large sample sizes (3,290 in 2002-04 and 5,423 in the 2012/13) which provided statistically accurate estimates for 46 individual stations. Between the two surveys, ten stations had been upgraded in a ‘major’ way; 29 stations had had a minor upgrade whilst 7 stations had remained ‘unimproved’.[90] Regression of the observed changes in passenger rating by station allowed the effect of station upgrading to be separated out. The application of the 3 step method enabled the rating effect to be valued.

Figure 49 shows the change in overall station rating for the 46 stations in the Wellington network over the ten year period. There was a general increase of around 5% but much bigger increases occurred at stations that had had major upgrades that involved rebuilding the main station.

Figure 49: Change in overall station rating 2002/04 – 2012 for Wellington Rail stations.



The rebuild of Naenae station, shown in Figure 50 (before and after) increased the overall station rating from 36% to 76%. In 2003, Petone station was rebuilt with bicycle racks and some other improvements added in 2010, see Figure 50.

[90] Stations that were ‘majorly’ upgraded were Petone, Epuni, Naenae, Plimmerton, Paraparaumu, Waikanae, Solway, Matarawa, Renall Street and Masterton.

Figure 50: Photographs of two Wellington rail stations before and after a major upgrade

A major upgrade of Naenae station was undertaken in 2012 with the platform surface renewed and the shelter replaced. The passenger rating increased from a weighted average of 32% in the 2002 and 2004 surveys to 76% in 2013. . Douglas

Petone station was rebuilt are reopened in March 2004. Before the upgrade in 2002, the passenger rating was 46%. Further improvements like bicycle racks in the right hand side photo were made in 2010. The rating in 2013 was 75%, up 29%. (ND)

The overall station rating increased from 46% to 76%.[91] Waikanae station was rebuilt as part of electrification extension of the Kapiti coast rail line. The station rating increased 35% points from 41% to 76%.

A series of regression models were fitted to explain the change in the overall rating and in the individual attribute ratings across the 46 stations in terms of the level of upgrade and how many years had elapsed since the upgrade when the 2012 survey was undertaken.

Table 62 presents the benefit of station upgrading to boarding passengers. The value of a major station upgrade is given at the bottom of the table. Upgrading (which typically involved rebuilding the main station building) was worth 3.99 minutes per passenger boarding. This is the ‘brand new’ value of benefit i.e. the day after completion. The rating and hence value then decreased such that after 5 years, the upgrade was worth 2.35 minutes and 0.36 minutes after 10 years. Figure 51 plots the estimated benefit.

[91] In Figure 49, Petone is shown twice PET1 and PET2 because it was surveyed three times before it was first upgrade in 2002, in 2004 after the first upgrade and in 2012 after a second upgrade.

Table 62: Value of rail station upgrading to boarding passengers in IVT minutes

Upgrade	Attribute Rating Affected	Valuation		Comment
		Minor Upgrade	Major Upgrade	
Platform Shelter	Shelter	0.10	0.40	Based on predicted effect on weather protection rating.
Seating	Seating	0.14	0.40	
Platform Surface	Platform Surface	0.17	0.39	Major upgrade included rebuilding platforms with access paths to 'street'.
" " "	Platform On/off	0.23	0.37	
Information	Information	na	0.27	
Lighting	Lighting	0.09	0.19	
Cleaning/Graffiti	Cleanliness/Graffiti	0.33	0.87	
Toilets	Toilet	na	0.03	
Retail	Retail	na	0.33	Opening of café/small shop on platform or near platform.
" " "	Staff	na	0.02	'Staff' presence from retail facility
" " "	Ticket Purchase	na	0.49	Ability to sell rail tickets from retail outlet.
Car Park	Car Access	na	0.20	Major upgrade of car parking area including resurfacing, lighting, signing and walkways.
Bus Facilities	Bus Access	na	0.01	Improvement of bus waiting area including shelter and signage.
Overall Station	Sum of Attributes	1.05	3.96	Sum of individual valuations
Station Upgrade	Overall Rating	1.06	3.99	Valuation of major upgrade on opening day, on year 5 and on year 10.
After 5 years	" " "	na	2.35	
After 10 years	" " "	na	0.36	

Figure 51: Passenger benefit of station upgrading to boarding passengers of station by year

Value in IVT minutes

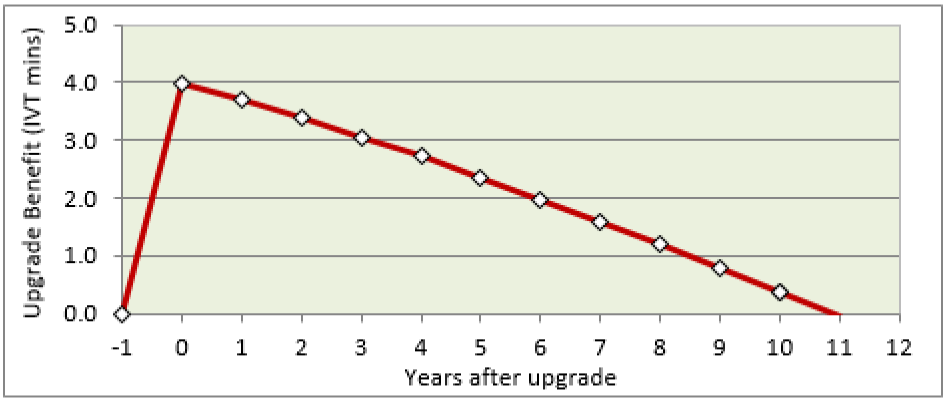


Table 62 also shows the passenger benefit of upgrading specific attributes such as platform shelter and seating. The regression analysis established how upgrades could increase more than one rating (the halo effect). As an example, the provision of retail facilities (with staff) increased the rating of ease of ticket purchase and the staff availability and helpfulness rating in addition to the retail rating. The combined benefit was 0.68 minutes.[92] When summed, the attribute upgrades totaled 1.05 minutes for a minor upgrade and 3.96 minutes for a major upgrade which was virtually the same as the upgrade ‘package estimate’ of 3.99 minutes given at the bottom of the table.

9.8 Valuing station upgrades & new stations in NSW

Station rating surveys in NSW were undertaken between 2004 and 2014 and altogether 9,970 passengers were surveyed.[93] The surveys were split into two periods: 2004-08 and 2009-14. Although ratings for 197 of the 308 stations in the network were obtained, only 46 stations had sample sizes of at least ten for both periods. Figure 52 provides photographs and descriptions of 4 major upgrades.

To assess the impact of upgrading, stations were classified according to whether they had a ‘major upgrade’ involving rebuilding the concourse/over-bridge to install lifts or reposition the station for track amplification; or been ‘upgraded’ e.g. replaced platform canopies; or not been upgraded.

Figure 52: Examples of Major NSW Station Upgrades

Glenfield (opened 1869, 33 kms south of Central on the Main South, South and East Hills rail line) has 4 platforms (2 island). A major upgrade was completed in 2012 as part of building the SW Rail Link. The upgrade included new lifts, a new aerial concourse, upgraded platforms and platform canopies. A new ticket office, toilets, bus interchange, passenger drop off facilities and additional security cameras and lighting were also installed. The passenger rating increased from 46% to 73%. The value of the rating increase was worth 4 minutes IVT for boarding passengers.


Newtown station (opened 1892 in current location) has an island platform located in a shallow cutting. A major upgrade was completed in Oct 2012 with new platform canopies, resurfacing plus a new station concourse and entrance with lifts and redesign of the surrounding precinct. The old station entrance shown is on the left and the new entrance on the right. The upgrade increased the passenger rating from 53% (2004/7) to 78% in 2013. The rating increase was worth 3.6 minutes IVT.


[92] Given that the ratings that were indirectly affected were determined by the regression analysis and then valued, halo effects were not also included as this would double count the effect.

[93] An earlier 1994 survey was undertaken but only aggregated reported results were available.

Woolooware opened in 1938 is on the Cronulla line. In 2010, the side platform (left photo) was converted to an island platform (right) with a new overhead concourse with lifts installed as part of Caringbah-Cronulla duplication. Station modernisation led to an increase in the passenger rating from 57% in 2004 to 83% in 2012. The rating increase was worth 3.7 minutes IVT.



Kirrawee on the Cronulla line 27 kms from Central, opened in 1939 as a single platform station (LHS photo) and was rebuilt (completed 2010) as an island platform as part of duplication of the Cronulla line. The station rating increased from 62% to 76% but was excluded from analysis due to small samples sizes (both 9).



Figure 53 presents the change in station passenger rating with the 48 observations sorted into major upgrade (red squares), upgrade (blue diamonds) and no upgrade (green circles) and placed in descending order of the rating increase. Also shown is the standard error which reflects the sample sizes of the two estimates.[94] Summary statistics are provided below the graph. A major upgrade increased the rating by 22% and an upgrade by 9% whereas at stations with no upgrade (effectively the control group) the rating increased by 2%.

The estimates are however 'crude' because no allowance was taken of the year of upgrade. Earlier upgrades (i.e. those undertaken closer to 2004 than 2014) would be expected to have had some of their effect eroded compared to later upgrades. Also stations where the survey years were closer together (e.g. Macquarie Uni surveyed 2009 and 2014) would have less of a difference that stations surveyed ten years apart (e.g. Eastwood surveyed in 2004 and 2014).

The analysis therefore took account of the length of time between the upgrade and the second survey with a regression fitted to the data. The rating difference was then adjusted to equal the brand new rating post an upgrade.[95]

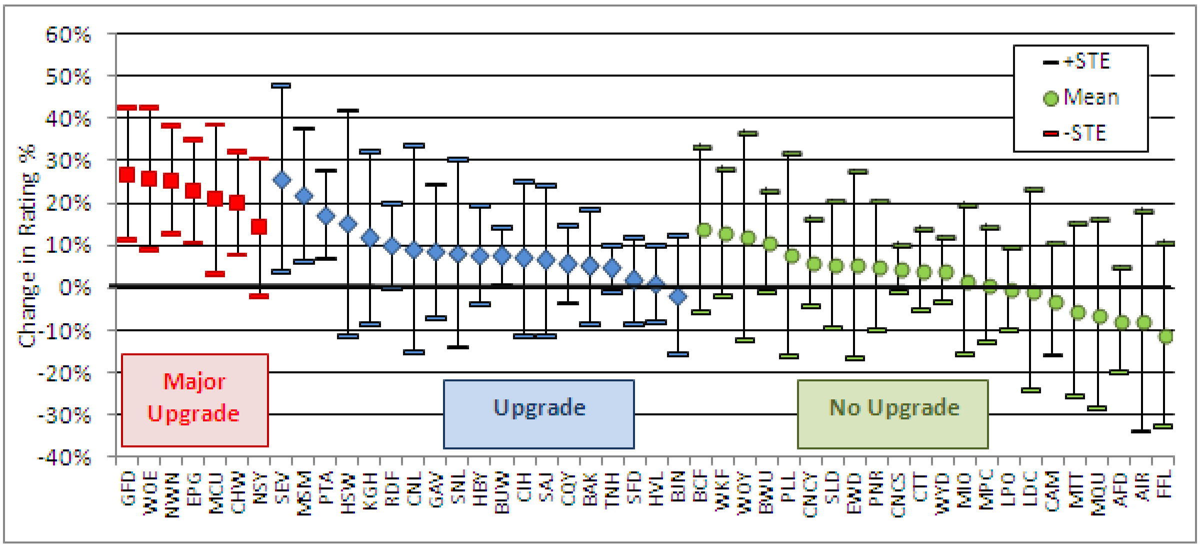
---

[94] The standard error of the rating difference was calculated from the standard deviations and sample sizes:

$$Var(R\%2 - R\%1) = \left\{StDev(R\%1)/\sqrt{N1} + StDev(R\%2)/\sqrt{N2}\right\}^2$$

[95] As an example, the second survey at Glenfield was undertaken in 2014 (four years after the completion of the major upgrade in 2012). If the second survey had been taken just after completion, the predicted rating would have been 80% (7% points higher than the surveyed rating of 73%).

Figure 53: Change in NSW Station Ratings according to level of station upgrading



Upgrade	Average Rating 2004-08	Average Rating 2009-14	Difference in Rating (2-1) Average	Min	Max	Stations
Major Upgrade	52%	74%	22%	14%	27%	7
Upgrade	59%	68%	9%	-2%	26%	19
No Upgrade	63%	65%	2%	-11%	14%	22
All Stations	59%	68%	9%	-11%	27%	48

The adjusted ratings after upgrading were compared against the base rating which as Figure 54 shows was greater at stations where the base rating was lower. The relationship was most pronounced for major upgrades. A constrained regression (equation 9.2) was fitted which ensured that if the base rating was 100%, 'upgrading' would have zero effect whereas if the base rating was 0%, upgrading would have maximum effect.[96]

$$\Delta R\% = \beta_y \Delta YEARS + \beta_{mu} MAJORUPG + \beta_{mub} MAJORUPG(R\%_1)$$
$$+ \beta_u NONMAJORUPG + \beta_{ub}(NONMAJORUPG)R\%_1 \qquad .....(9.2)$$
$$where: \beta_{mu+}\beta_{mub} = 0 \,\&\, \beta_u + \beta_{ub} = 0$$

The estimated parameters are shown in Table 63. For a hypothetical station with a zero base rating, a major upgrade would increase the station rating to 55.1% points. If the base rating was 50%, the increase halves to 27.5% and if the base rating was 100%, the upgrade would have zero effect.

Figure 55 graphs the predicted rating increase for different base ratings. A lookup table is provided on the left. For the seven major upgraded stations which had an average base rating of 52%, the predicted increase immediately after completion was 26% points.[97] For non-major upgrades, the

[96] The parameters were constrained such that βmu + βmub =0 and βu+βub = 0

[97] The increase for a major upgrade which was 6% points higher than the unadjusted estimate of 20% (after deducting 2% points for the underlying general trend in rating). The upgrade increase was 1% higher than the unadjusted estimate of 7%.

predicted increase was 8% on a base rating of 59%.

Figure 54: Increase in NSW Station Rating against Base Rating

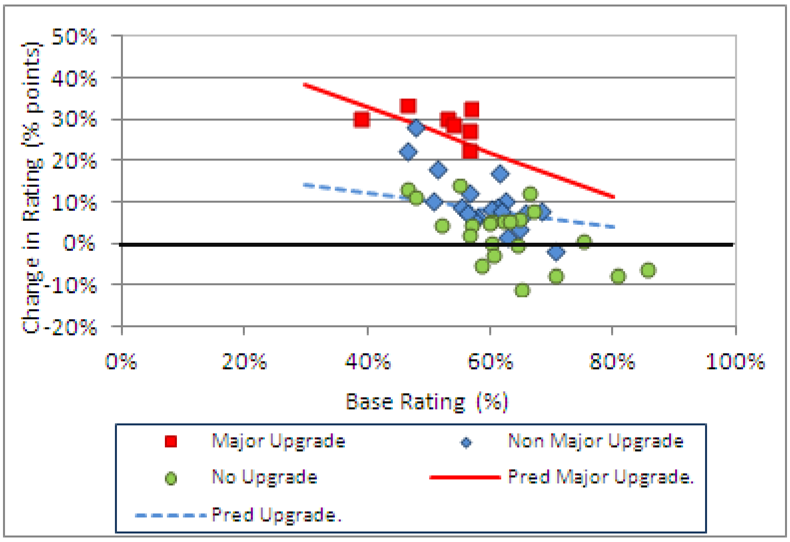


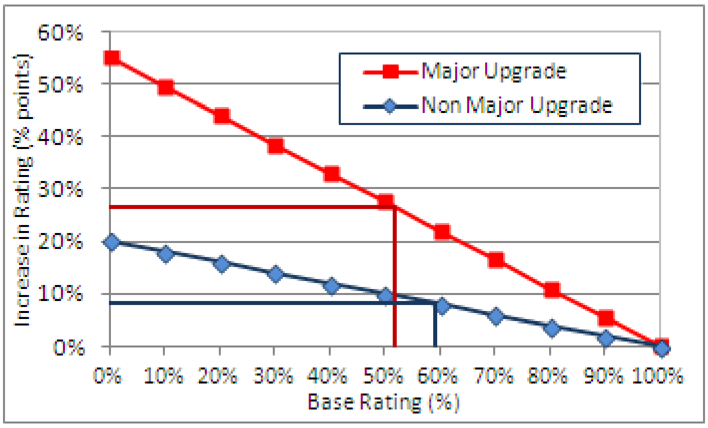
Table 63: Effect of Base Rating on Predicted Rating of Station Upgrading

Variable	β	STE	|t|
Major Upgrade	0.551	0.054	10.1
Major Upgrade Base Rating %	-0.551	0.054	10.2
Non Major Upgrade	0.202	0.046	4.4
Non Major Upgrade Base Rating	-0.202	0.046	4.4
Years (between surveys)	0.030	0.015	2.1

Model fitted on 48 observations. Adjusted R^2= 0.68

Figure 55: Predicted Increase in NSW Station Rating for Different Base Rating

Base	Upgrade Rating Increase	
Rating %	Major	Non Major
0%	55%	20%
10%	50%	18%
20%	44%	16%
30%	39%	14%
40%	33%	12%
50%	28%	10%
60%	22%	8%
70%	17%	6%
80%	11%	4%
90%	6%	2%
100%	0%	0%



The NSW rating surveys also included eight new stations that had opened between 2004 and 2014. Seven were underground stations and one was a surface station.[98] Figure 56 provides photographs of two stations.

Table 64 presents the new station ratings. The survey rating is given and also a predicted rating for the station if it had been brand new.

Figure 56: Examples of New Stations

Oak Flats on the Illawarra line 105kms south of Central was opened in 1925 then rebuilt in a new location in 2003. The station has a single platform. There is a commuter car park and bike racks and lockers. The station scored a passenger rating of 76% with most surveys undertaken in 2010 seven years after opening. If surveyed on opening, the rating was predicted to have been 86%.

Macquarie Park on the Epping- Chatswood rail line 21 kms from Central opened in February 2009. The station has an underground concourse with platforms underneath connected by escalators and lifts to the surface. The station was highly rated scoring 88% when 4.8 years old and was predicted to have had a rating of 92% on opening.

Wolli Creek, an interchange station on the East Hills/Airport and Illawarra lines 7.3 kms from Central, opened in 2000. The station has 4 platforms: 2 surface (Illawarra) and 2 below ground platforms (Airport line). The station rated at 66% 12 years after opening and was predicted to have had a rating of 83% on opening.

[98] Four stations were on the Airport Rail: Domestic /International (combined), Green Square, Mascot and Wolli Creek which opened in 2000. Three stations were on the Epping-Chatswood rail line: Macquarie Park, Macquarie University and North Ryde. The eighth station was Oak Flats which was rebuilt at a new location in 2003. Six stations were underground. Wolli Creek had below ground as well as surface platforms and Oak Flats was a surface station.

Table 64: Surveyed and Predicted Ratings for New Stations in NSW

Station	Overall Station Rating (%)				Station	Predicted
	Mean	StdDev	N.Obs	StdErr	Age Yrs+	'New' Rating*
Domestic/International	74%	20%	64	3%	11.5	87%
Green Square	83%	17%	13	5%	13.2	92%
Mascot	75%	17%	32	3%	13.0	88%
Wolli Creek	66%	24%	29	4%	12.1	83%
Macquarie Park	88%	13%	10	4%	4.8	92%
Macquarie Uni	85%	12%	138	1%	0.5	87%
North Ryde	80%	18%	7	7%	4.9	88%
Oak Flats	76%	17%	50	2%	6.4	86%
Average	79%	17%	343	1%	6.2	88%

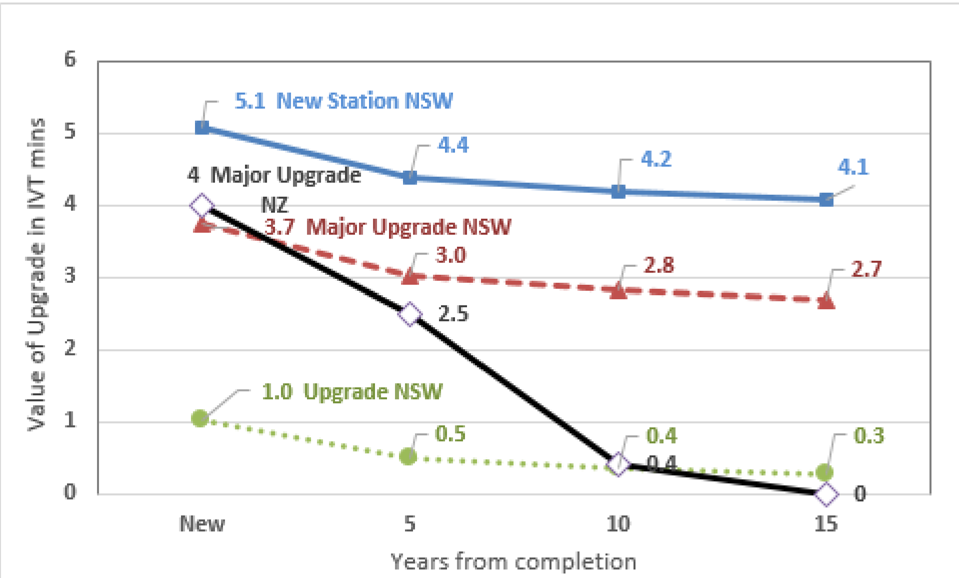
+ average age of station when surveyed, * predicted rating of station when brand new.

Models were assess the effect of station ageing. Taking the square root of station age gave the best fit. The age parameter for new stations and major upgrades was -0.03. For upgrades, the parameter was -0.02.

Figure 57 estimates the value of new and upgrade stations in IVT minutes for boarding passengers using the valuation methodology (0.7 power parameter and 18 minute maximum station quality value). The value of 'new' station has no base reference station unless it is a replacement (e.g. Oak Flats). The average system rating could be used or a similar station close by. The graph uses a base of 52%, the same as the major upgrade which was taken from the surveys. The non-major upgrade is calculated for a 59% base which was also taken from the surveys. On these assumptions and using the predictive models outlined, a new station would benefit station boarders by 5.1 minutes of IVT; a major upgrade by 3.7 minutes and a non-major upgrade by 1 minute. The benefit is then predicted to decline to 4.1 minutes for a new station (allowing for the base rating to also decline) to 2.7 minutes for a major upgrade and to 0.3 minutes for an upgrade.

Figure 57: Value of New and Upgraded Stations

Valued in IVT minutes for boarding passengers



The major upgrade value of 3.7 minutes is similar to the NZ value of 4 minutes. Where they differ is in terms of the rate of decline. The NSW rate of decrease is flatter.

The rating approach can also be used to value the 'disruption' disbenefit to passengers during a station rebuild. As an example, the evaluation of upgrade options for Redfern station (Douglas 2009), included a passenger disbenefit from a predicted drop in rating during the rebuild of 3% points.

9.9 De Gruyter review of stop and station amenity values

The De Gruyter (et al) international review which was described briefly in section 8.9 tabulated a long list of amenity vales for bus stops, tram/LRT stops and train/metro stations.

Values were classified into access/egress and waiting. Table 65 presents the access/egress values and Table 66 the waiting values. The bottom row of Table 66 provides a grand total by adding the access/egress value to the waiting value.

The grand total value for train stations was 2.82 minutes. Waiting amenity was 2.82 minutes and accounted for 80% and access/egress at 0.61 minutes accounted for 20% of the total value.

For bus stops the grand total at 4.59 minutes was somewhat surprisingly higher (1.6 times) than for rail stations. Access/egress 'amenities' accounted for 1.43 minutes and waiting amenities 3.16 minutes. As with vehicles, De Gruyter was unable to find many values for tram and Light Rail stops.

As with the vehicle values, the range was very wide reflecting high valuations estimated by some studies which when summed gave a range for rail stations of 0.13 to 54 minutes and a range of 1.2 to 47 minutes for bus.

Table 65: Value of bus stop and train/metro station 'access/egress' amenity values – De Gruyter review

Amenity and (type)	Train/Metro			Tram/LRT			Bus		
		Range			Range			Range	
	Med	Low	High	Med	Low	High	Med	Low	High
Access/Egress values									
Bicycle parking o/s stations/stop (A,F)	0.31	0.02	0.60						
Building exterior station/stop (C)	0.10								
Car parking	0.36	0.01	1.80						
Directional signage to station/stop (I)							0.68	0.37	0.98
Entrance visibility to station/stop (A)							0.50		
Lighting (S)							0.57		
Pedestrian crossing (A)									
Onwards connections o/s stat/stop (A)	0.07	0.01	0.60				0.35		
Step free access to stat/stop (A)	0.64	0.15	0.93				1.02		
Taxi rank o/s stat/stop (A)	0.16	0.01	0.30						
Wide ticket barrier gates (A)							0.10		
Access/Egress Values by Type									
Access (A)	0.15	0.01	0.93				0.36	0.10	1.02
Facilities (F)	0.36	0.01	1.80						
Information (I)							0.50	0.37	0.98
Security (S)							0.57		
Condition (C)	0.10								
Access/Egress Total	*0.61*	*0.02*	*2.73*				*1.43*	*0.47*	*2.00*

Table 66: Value of bus stop and train/metro station 'waiting' amenity values – De Gruyter review

Amenity and (type)	Train/Metro			Tram/LRT			Bus		
		Range			Range			Range	
	Med	Low	High	Med	Low	High	Med	Low	High
Waiting amenity values									
Air quality (E)	0.20	0.06	1.80				0.18	0.03	1.27
Appearance of station/stop (C)									
Art (C)									
ATMs (F)									
Cabling (C)									
Cleanliness of station/stop (S)	0.50	0.13	13.99	1.21			0.39	0.10	2.07
Clocks (I)	0.20						0.10		
Draughts (E)									
Directional signage (I)	0.30	0.05	1.80				1.20		
Electronic display/RTI (I)	2.75	0.12	6.00	0.48	0.30	0.65	0.99	0.10	10.95
Escalators (A,F)	0.12	0.03	0.20						
Grafitti (S,C)	0.30	0.05	0.97				0.46	0.10	0.55
Ground/floor surfacing (C)	1.07	0.63	1.80						
Help point (I,S)	0.67	0.08	3.96				0.10		
Info/emergency button (I)	0.35	0.03	1.80				0.75	0.50	1.60
Info on outside of vehicle (I)									
Info on system disruptions (I)	1.00	0.10	2.12				1.12	0.93	1.31
Lifts (A,F)	0.22								
Lighting (S)	0.40	0.03	7.93	0.35	0.22	0.48	0.54	0.10	1.20
Litter (S,C)	0.50	0.32	0.91				0.22	0.14	0.24
Luggage storage (F)									
Map of local surrounding area (A,I)							0.87	0.20	1.74
Map of PT routes (A,I)							0.61	0.20	0.60
Map of station area (A,I)									
Mirrors (S)							0.02		
Mobile phone RTI (I)							0.16	0.12	0.20
PA System (I,S)									
Photo booth (F)									
Police (S)							1.09	0.96	1.23
Posters (I,C)									
Public telephones (F,C)	0.16	0.01	2.00				0.49	0.10	0.67
Retail/food outlets (F)	0.19	0.05	0.90				0.35	0.30	0.40
Rubbish bins (F)									
Seating (F)	0.40	0.04	4.80	0.43	0.32	0.54	0.60	0.10	13.78
Shelter/platform canopy (F)	0.40	0.00	9.40	0.52	0.48	9.40	0.81	0.14	1.70
Staff (I,S)	0.57	0.09	12.01	0.09			0.24	0.13	1.10
Step free access (A)									
Surveillance cameras (S)	1.02	0.06	4.83				0.99	0.30	2.91
Temperature control heating/cooling (E)	0.20	0.11	0.29				1.98		
Timetables (I)	1.52	1.20	1.52	0.31			0.74	0.40	1.09
Ticket machines (F,C)	0.21	0.10	0.30	0.33					
Ticketing options (F)	0.40	0.16	0.66	0.51			0.20	0.10	1.43
Toilets (F,C)	0.33	0.01	7.93				0.46	0.22	0.70
Waiting room (F,C)	0.64	0.03	1.35						
Wi-fi access (F)									
Waiting by Type									
Access (A)	0.20	0.03	0.22				0.64	0.10	1.74
Facilities (F)	0.30	0.00	9.40	0.50	0.32	0.55	0.49	0.10	13.78
Information (I)	0.52	0.03	12.01	0.30	0.09	0.65	0.70	0.10	10.95
Security (S)	0.50	0.02	13.99	0.22	0.09	1.21	0.43	0.10	2.91
Environment (E)	0.29	0.03	1.35				0.47	0.34	1.98
Condition (C)	0.40	0.00	13.99	0.48	0.32	0.55	0.43	0.03	13.78
Waiting Total	*2.21*	*0.11*	*50.96*	*1.50*	*0.82*	*2.96*	*3.16*	*0.77*	*45.14*
TOTAL Access/Egress + Waiting	2.82	0.13	53.69	1.50	0.82	2.96	4.59	1.24	47.14

10. Mode Specific Constants

10.1 Introduction

Mode Specific Constants (MSCs)[99] measure the residual difference in modal quality after differences in travel convenience notably access/egress time, in-vehicle time, service frequency, transfer, crowding, reliability and fare have been deducted.[100]

MSCs are often used in multi-modal studies such as forecasting the patronage for new services such as a new Bus Rapid Transit route or a new Light Rail service where there may be an absence of information to 'position' the proposed new mode relative to existing public transport services.

As the previous two sections have shown, the quality of vehicles, stops and stations will vary with the age, facilities and operational aspects (i.e. cleanliness and staff). Distilling the 'intrinsic' MSC from the 'gross' MSC (which includes age, facility and operational aspects) can ensure that the nature of the comparison is understood. Is the proposed service being compared with, for example, an elderly bus fleet that would probably be replaced in 5 or so years? Should the comparison instead be 'like for like' (i.e. new versus new or mid-age versus mid-age).

Fourteen Australia and NZ studies provided MSC estimates. Eleven of the studies were undertaken as part of producing patronage forecasts for new transport services and for these estimates it is probably unlikely that the reported MSCs were purely 'intrinsic' since often a brand 'new' service was compared with a 'mid aged' existing service (at least in the eyes of the respondent). Moreover, the estimates reflect perceptions of future services rather than actual experience of existing services and are therefore more prone to misperception and potential 'policy response bias' (deliberately responding to influence a policy decision rather than reflect likely future use).

Two of the studies used observed travel data of existing services and such data has advantages over 'stated preferences', there is the disadvantage that the MSCs may incorporate statistical modelling artefacts rather that solely measure passenger preferences.

10.2 Gross Mode Specific Constants

Four gross MSCs, expressed in IVT minutes, were estimated for rail, LRT, Transitway (Busway) and Ferry. The MSCs compare each mode to travelling by bus.

The Bus – Ferry MSC was the largest at 16 minutes but should be treated with caution since it was based on only one Sydney study undertaken in 2001 (19). The bus trip time was estimated at 40 minutes which implies an IVT multiplier of 0.4.

The Bus – Transitway (Busway) – MSC was the smallest at 5 minutes for a 40-minute trip implying an IVT multiplier of 0.12.

The Bus-Rail MSC was 10 minutes calculated on 22 observations from 13 studies. When divided

[99] Sometimes referred to as Alternative Specific Constants (ASCs).

[100] Of the convenience factors, frequency, in-vehicle time, fare and transfer are the easiest to separate out. Access, crowding and reliability are more difficult and often the MSC will include them either partially or fully.

by average trip length (33 minutes), the MSC time multiplier was 0.3. It is worth noting that the IVT times for bus and rail are likely to differ. The recommendation is to apply the IVT multiplier to bus and use the bus IVT.

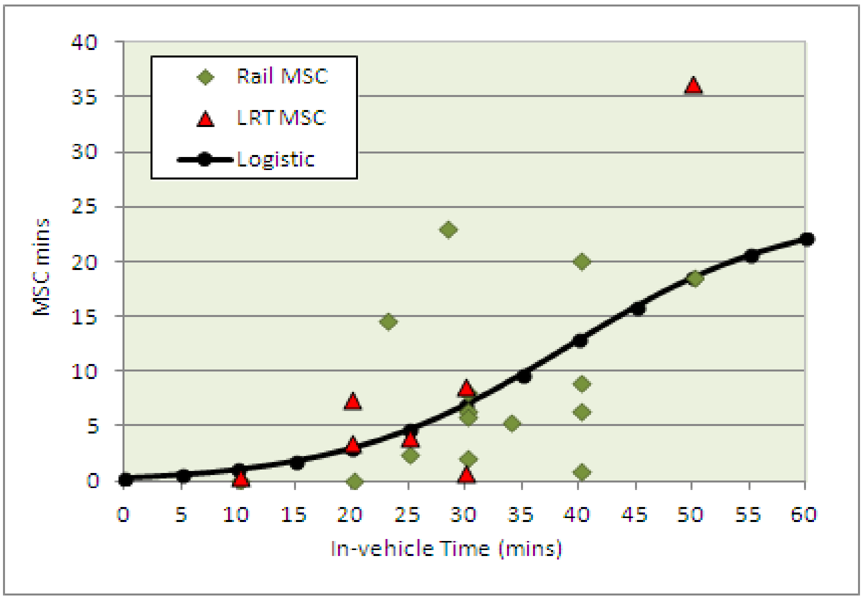
For LRT-Bus MSC was 12 minutes based on 10 observations from 4 studies. The MSC was therefore 2 minutes larger than the Rail-Bus (10 minutes). In 3 of the 4 studies, LRT was a 'new' mode thus the evidence for a higher LRT constant was therefore not compelling.

Table 67: Mode Specific Constants in IVT minutes

	Bus - Rail	Bus - LRT	Bus-(Rail/LRT)+	Bus - TW	Bus - Ferry
MSC mins	10	12	7	5	16
Bus IVT mins	33	28	30	40	40
MSC Multiplier	0.30	0.43	0.23	0.12	0.40
MSC 75%tile	14	15	na	6	25
MSC Median	6	4	na	5	18
MSC 25%tile	0	1	na	4	7
Obs	22	10	32	5	3
Studies	13	4	13	4	1

The third column presents a combined Rail/LRT MSC based on a regression (logistic) of the 32 observations taking account trip length. Figure 58 presents the data.[101] There was little difference between rail and LRT. For a 30 minute trip, the MSC was 7 minutes implying an IVT multiplier of 0.24.

Figure 58: Estimated LRT/Rail-Bus MSC in IVT minutes



ParameterLibrary10.xlsASCATGuidelines

[101] The fitted regression line was -8.8+0.564(IVT) with t values of 1.8 for the constant and 3.7 for the slope parameter with observations weighted according to the relative t value.

The MSC increased with trip length. For trips under 15 minutes, a linear regression would have predicted a negative MSC (i.e. a preference for bus). However, the 'estimate' would have been largely by extrapolation since the shortest observed trip length was 10 minutes.

There were few observations of trips longer than 40 minutes so care should be taken in extrapolating the results. Equations 10.2.1 and 10.2.2 set out the logistic model with Table 68 presenting the predicted MSCs for trips ranging from 5 minutes to 1 hour (bus times).

$$MSC = -0.2 + 25(Z) \quad .....(10.2.1)$$

Where $Z = \frac{\exp(\alpha + \beta IVT)}{1 + \exp(\alpha + \beta IVT)}$ .....(10.2.2)

with estimated parameters of

Estimated parameters: $\alpha = -3.95 \ t = 5.3$ and $\beta = -0.102 \ t = 4.4$ with weighted observations.

Table 68: LRT/Rail - Bus predicted MSC

Bus IVT mins	5	10	15	20	25	30	35	40	45	50	55	60
MSC (mins)	0.6	1.1	1.8	3.0	4.6	6.9	9.7	12.9	15.9	18.6	20.6	22.1
IVT multiplier	0.11	0.11	0.12	0.15	0.19	0.23	0.28	0.32	0.35	0.37	0.37	0.37

For a 25-minute trip, the IVT multiplier is 0.19 minutes. The multiplier is therefore close to the 'quality control' value of 0.2 recommended by the US Federal Transit Administration (FTA) for forecasting rail and LRT patronage for 'new start' funding applications (FTA, 2006).[102]

10.3 Intrinsic Mode Specific Constants and quality difference

The Sydney 2013 study (38) attempted to estimate an intrinsic Mode Specific Constant for LRT and rail compared to bus after standardising for differences in quality (measured by ratings).[103] The study found little difference in the intrinsic MSC between LRT and rail. For LRT/Rail versus bus, a 2.7 minute intrinsic MSC was estimated for a 25-minute trip, an IVT multiplier of 0.11 (see Table 69).

Table 69: Bus – (LRT/Rail) intrinsic mode specific preference

	IVT mins	Per Min^
Intrinsic Modal Preference	2.7	0.11

^ for a 25 minute trip

[102] The FTA values were the mirror image of 0.8 which was multiplied with the rail time when compared to bus (i.e. the mirror image of a 0.2 bus time multiplier).

[103] Passengers may rate modes differently because their expectations of quality may differ (i.e. their 'rating ruler' varies by mode). To address this, the Sydney survey asked passengers to also rate the alternative mode based on their experience of using it. Bus users therefore rated Sydney Light Rail (if they had used it) and/or Sydney rail services. The study found a tendency for respondents to rate their current mode higher than the 'alternative' and as a result, the ratings for all three modes reduced but the rating differences remained roughly the same.

Having established the 'intrinsic' MSC, differences in stop/station and vehicle quality can be added. Table 70 sets out the calculation for different quality ratings for a 25-minute trip.

Given that different modes are being compared, average values for the maximum valuation of quality (0% to 100%) have been used. As can be seen, for a 25-minute trip, the stop/station and vehicle quality values are quite similar.[104]

Table 42 (vehicles) and Table 57 (stop/stations/wharves) presented the range in bus, LRT/tram and train ratings. Vehicles averaged 73% and stops/stations/wharves 68%. New systems are likely to improve on the average rating. To illustrate the approach, a proposed LRT system is assessed where the vehicle rating increases from 70% to 80% and the stop/station rating from 65% to 75%.

From Table 70, the vehicle quality improvement (70% to 80%) would be worth 1 minute per trip (10.36 to 11.38) with the stop quality improvement (65% to 75%) worth 1.1 minutes (10.36 to 11.45). Therefore, the combined quality improvement from the proposed LRT compared to the existing bus service would be worth 2.1 minutes.

Table 70: Value of vehicle and stop / station quality differences in IVT mins

Attribute	Max Quality	Valuation of Quality Rating (mins) for a 25 minute trip										
		35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%
Vehicle	13.3	6.4	7.0	7.6	8.2	8.8	9.3	9.8	10.4	10.9	11.4	11.9
Stop	14.0	6.7	7.4	8.0	8.6	9.2	9.8	10.4	10.9	11.4	12.0	12.5
Total	na	13.1	14.4	15.6	16.8	18.0	19.1	20.2	21.3	22.3	23.4	24.4

Maximum Stop Quality = 12 minutes for boarders plus 2 minutes for alighters (see Table 50)

Maximum Vehicle Quality = Vehicle 3.2 + 0.405 per minute (see Table 35)

The value of the quality improvement can then be added to the intrinsic MSC difference of 2.7 minutes to get a gross MSC of 4.8 minutes for the 25-minute trip. In this example, quality therefore accounts for 44% of the gross MSC and intrinsic MSC 56%.

The gross MSC of 4.8 minutes is close to the 4.6 minute figure predicted by the logistic model in Table 68 for a 25 minute trip.

[104] The total stop/station value could be increased to take account of alighting passengers benefiting. This could be done by using the figures in Table 50.

References

AECOM 2009, *The Role of Soft Measures in Influencing Patronage Growth and Modal Split in the Bus Market in England" Final Report for the UK Department of Transport*, October 2009.

Atkins, S, Bottom, C, Sheldon, R, Heywood, C & Wardman, P, *Passenger Information at Bus Stops: Results from the London Countdown Route 18 Monitoring Study",* PTRC Seminar E 1994.

Balcombe et al. 2004, *The Demand for Public Transport: A Practical Guide* (TRL 593).

Bates, J, Polak, J, Jones, P & Cook, A 2001, *The Valuation of Reliability for Personal Travel,* Transportation Research Part E, 37, pp.191-229.

Batley R., Bates J., Bliemer M., Uncle Cobley T, etc … and Wardman M. *"New Appraisal Values Of Travel Time Saving & Reliability in Great Britain"* Journal of Transportation 2018.

Beca Carter Hollings & Ferner in association with SDG, Forsyte Research Brown Copeland & Co 2002, *Evaluation Benefit Parameter Values,* report to Transfund April 2002.

Booz Allen and Hamilton and PCIE 1995, *Ultimo – Pyrmont Light Rail CBD Patronage Study,* report for NSW Department of Transport.

Booz Allen Hamilton 2000, *Modelling Parameters for use in Auckland Public Transport Model*, report to ARC.

Booz Allen Hamilton and PCIE 2001, *Market Research Sydney Ferries,* report for State Transit NSW.

Booz Allen Hamilton and PCIE 2003, *Sydney Light Rail Stated Preference Survey Report,* report to DIPNR dated September 2003.

Booz Allen Hamilton and PCIE 2003, *ACT Transport Demand Elasticities Study,* report to Department of Urban Services, Canberra, February 2003.

Bristow, A L & Davison, L J 2009, *The Determinants of Bus Patronage in England – Literature Review,* report undertaken as part of Aecom (2009) study (see above).

Carrion, C & Levinson, D 2012, *Value of Travel Time Reliability: A Review of Current Evidence*, Transportation Research A (46), pp.720-741.

CRC 2010, *‚A Socio Economic Study of Platform and Carriage Crowding in the Australian Railway Industry,* summary report on stage 2 quantitative research.

Currie, G, Douglas, N J & Kearns, I, 2013, *An Assessment of Alternative Bus Reliability Indicators*, Australasian Transport Research Forum 2012 Proceedings 26–28 September 2012, Perth, Australia.

DAE (Deloitte Access Economics) 2016, *A scoping study for future research into values of travel time savings for project appraisal and toll road patronage forecasting*, report for the National Guidelines for Transport System Management in Australia.

De Gruyter, Graham Currie, Long T. Truong & Farhana Naznin (2018) "A meta-analysis and synthesis of public transport customer amenity valuation research" Transport Reviews

Douglas, N J, Franzman, L J & Frost, T W 2003, *Estimation of Demand Parameters for Primary Public Transport Service Attributes in Brisbane*, presented at the 26th Australasian Transport Research Forum, Wellington NZ Oct 1–3 2003.

Douglas, N J & Karpouzis, G 2005*, Estimating the Passenger Cost of Station Crowding*, paper presented at the 28th ATRF, Sydney, Sept 2005.

Douglas, N J & Karpouzis, G 2006, *Valuing Rail Service Quality Attributes through Rating Surveys,* 29th Australasian Transport Research Forum, Gold Coast, 2006.

Douglas, N J & Karpouzis, G 2006, *Estimating the Passenger Cost of Train Crowding,* paper presented at the 29th Australasian Transport Research Forum, Gold Coast, September 2006.

Douglas, N J, Karpouzis, G, Rahman, A 2010, *Forecasting the Use of Passengers Lifts at Rail Stations*, ATRF Canberra 2010.

Douglas, N.J. & Karpouzis, G. (2011). *"Tracking the value of rail time over time".* Conference paper delivered at the 34th Australasian Transport Research Forum (ATRF) Proceedings held on 28 - 30 September 2011 in Adelaide, Australia.
https://www.researchgate.net/publication/241809178/download

Douglas, N. J & Legaspi, J 2018, *Estimating the Value of Private Car Travel Time and Reliability for NSW*, 28th Australasian Road Research Board conference, Brisbane 2018.

Douglas, N J 2011, *Estimating the user benefit of rail station lifts*, paper presented the 34th Australasian Transport Research Forum, Adelaide 2011.

Douglas, N J & Jones, M 2013, *Estimating Transfer Penalties & Standardised Income Values of Time by Stated Preference Survey,* ATRF Brisbane 2013.

Douglas, N J 2014, *Who are your urban bus passengers and what are they willing to pay for?,* paper presented to the NZ Bus and Coach Association 2014 Conference, Auckland July 11th 2014.

Douglas N.J. 2015, *Valuing Public Transport Service Quality using a Combined Rating & Stated Preference Survey*, paper presented at the 37th Australasian Transport Research Forum, Sydney,

Douglas N.J. 2016, *Passenger Preferences for Surface versus Underground Rail Travel,* paper presented at the Australasian Transport Research Forum 2016 Proceedings 16-18 November 2016, Melbourne, Australia
https://www.researchgate.net/publication/311067180_Passenger_Preferences_for_Surface_versus_Underground_Rail_Travel

Douglas N.J. and Jones M. (2016) *"Developing a Suite of Demand Parameters for Inner Sydney Public Transport"* Australasian Transport Research Forum 2016 Proceedings 16-18 November 2016, Melbourne, Australia.
http://atrf.info/papers/2016/files/ATRF2016_Full_papers_resubmission_212.pdf

Douglas N.J. (2017) *"Valuing Ferry Service Quality using a Combined Rating & Stated Preference Survey"* Paper presented at the Australasian Transport Research Forum 2017 Proceedings 27 – 29 November 2017, Auckland, New Zealand. http://atrf.info/papers/2017/files/ATRF2017_100.pdf

Douglas N.J. (2018) *"Valuing Public Transport & Wayfinding Information"* Paper presented at the Australasian Transport Research Forum 2018, Darwin, Australia. https://www.researchgate.net/publication/328737432_Valuing_Public_Transport_Wayfinding_Information

Douglas Economics 2004, *Sydney CBD LRT Stated Preference Market Research Results,* report to Department of Planning, Infrastructure & Natural Resources NSW by Douglas Economics, January 2004.

Douglas Economics 2004, *Value of Station Crowding,* RailCorp Investment Evaluation Unit.

Douglas Economics 2005, *Tranz Metro Passenger Survey,* report to Tranz Metro by Douglas Economics, April 2005.

Douglas Economics 2006, *Passenger Ratings and Priorities for Improvement in Rail Service, 2004-5 Survey,* report to RailCorp, August 2006.

Douglas Economics 2006, *Service Quality Ratings & Priorities for Improvement 2005-06 Survey*, report to RailCorp, August 2006.

Douglas Economics 2006, *Value and Demand Effect of Rail Service Attributes,* report to RailCorp, December 2006.

Douglas Economics 2009, *Economic and Financial Evaluation of Redfern Station Upgrade Options,* report to RailCorp, August 2009 by Douglas Economics.

Douglas Economics 2012, *Modelling Train & Passenger Capacity,* report to Transport (for distribution) for NSW by Douglas Economics, dated July 2012. The report can be accessed at http://www.smh.com.au/nsw/secret-report-casts-doubt-on-train-plan-20130922-2u7zg.html

Douglas Economics 2013, *Review of Public Transport Parameters,* report to Bureau of Transport Statistics NSW by Douglas Economics, March 2013.Douglas Economics 2013, *Passenger Service Quality Values for Bus, LRT & Rail in Inner Sydney,* report to Bureau of Transport Statistics NSW by Douglas Economics, August 2013.

Douglas Economics 2014, *Pricing Strategies for Public Transport - Literature Review,* report prepared for the New Zealand Transport Agency, January 2014.

Douglas Economics 2014, *Passenger Service Values for Bus, LRT & Rail in Sydney*, report to BTS & TfNSW, September 2014.

Douglas Economics 2016, *Service Quality Values for Sydney Rail* report to Sydney Trains.

https://www.researchgate.net/publication/329327098_Service_Quality_Values_for_Sydney_Rail

Douglas Economics & Sweeney Research 2014, *Information and Service Quality Values for Public Transport,* report to PTV, October 2014.

Douglas Economics 2015, *Service Quality Values of Rail Transport in Sydney,* report to Sydney Trains by Douglas Economics dated August 2015.

Duckenfield, A, Higbee, T, Holt, M 2010, *Measuring the benefits of the Access for All Programme,* European Transport Conference 2010.

Evmorfopoulos, A P 2007, *Valuing "soft" factors improvements in urban bus services,* MSc Dissertation, Institute for Transport Studies, University of Leeds.

Fearnley, N, Flugel, S & Ramjerdi, F 2011, *'Passengers' valuations of universal design measures* *in public transport'*, in Research in Transportation Business & Management January 2011.

Fox, J, Daly, A, & Patruni, B 2010, *Sydney strategic re-estimation mode-destination model,* report prepared for Bureau of Transport Studies, Transport NSW.

Fox, J, Patruni, B & Daly A. (2015) *"Sydney Strategic Model Re-estimation: Mode-Destination Model"*. Transport for New South Wales, 2015. https://www.rand.org/pubs/research_reports/RR1130.html.

Federal Transit Administration 2006, *Semi-independent Forecasts of Ridership and User Benefits for New Starts Projects,* discussion piece #9 by US Federal Transit Administration, June 6, 2006.

Federal Transit Administration 2006, *Illustrative Mode-Choice and Summit Calculations for Travel by One Market Segment between a Pair of Zones for Base and Build Alternatives,* Discussion piece #11 by US Federal Transit Administration, June 6, 2006.

Halcrow 2000, *Bondi Beach Rail Extension Patronage Study,* report for Lend Lease Capital Services - Macquarie Bank Joint Venture, February 2000.

Halcrow 2005, *Dandenong Rail Corridor Market Assessment Stated preference Survey of Train Passengers*, report provided to Department of Infrastructure Public Transport Division.

Hammer, F & Nordheim, B 1993, *Bus Passengers Valuation of Service Improvements – A Conjoint Analysis on the Basis of Market Surveys in three Norwegian Towns Institute of Transport Economics,* report 166 1993.

Hague Consulting 2001, *Sydney travel model based on Household Travel Survey calibration,* calibration report to Transport Data Centre, NSW, August 2001.

Hensher, D A & Rose, J M 2003, *The North-West Transport Study patronage survey, stated choice model estimation for work and non-work travel,* report to Department of Transport NSW.

Hensher, D A & Prioni, P 2002, 'A Service Quality Index for Area-wide Contract Performance Assessment', *Journal of Transport Economics and Policy 36* (1) 93-113.

Hensher, D A, Stopher, P, & Bullock, P 2003, 'Service Quality—Developing a Service Index in the Provision of Commercial Bus Contracts', *Transportation Research*, Vol. 37A, No. 6, 2003, pp. 419–517.

Hensher, D A, Rose, J M, Collins, A T 2011, 'Identifying commuter preferences for existing modes and a proposed Metro in Sydney, Australia with special reference to crowding', *Public Transport (2011)3:109-147 Case Studies and Applications,* published online Springer Verlag: 1 Feb 2011.

Ian Wallis & Associates 2008, *Wellington City Bus Priority Plan – Evaluation Draft 4,* report to Wellington City Council, 18 April 2008 by Ian Wallis & Associates Ref: N012/Rep/1056 study.

Institute for Transport Studies, Leeds University and Transport Research Institute, Napier University 2001, Development Department Research Programme Research Findings No 99; Interchange and travel Choice Scottish Executive Central Research Unit.

ITLS Sydney 2011, *Estimation of parameters to forecast demand for Metro services in NW Sydney*, report for NSW Department of Transport.

Kittleson & Associates, U, LKC Consulting Services Inc, MORPACE International Inc, Queensland

University of Technology, Yuko Nakanishi 2003, *A Guidebook for Developing a Transit Performance-Measurement System,* Transit Cooperative Research Program TCRP Report 88, Transportation Research Board Washington DC 2003.

Kroes, E, Kouwenhoven, M, Debrincat, L & Pauget, N 2013,*On the Value of Crowding in Public Transport in Île-de-France, OECD/ITF Discussion Paper 2013-18,* prepared for OECD/ITF Roundtable on Valuing Convenience in Public Transport, 12–13 September 2013, Paris.

Legaspi J and Douglas N.J. (2015) *"The value of travel time revisited"* Paper presented at ATRF 2015 Sydney.
https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/Value%20of%20Travel%20Time%20Revisited%20%E2%80%93%20NSW%20Experiment.pdf

Litman, T 2008, *Valuing Transit Service Quality Improvements: Considering Comfort and Convenience in Transport Project Evaluation,* research report, Victoria Transport Policy Institute, Victoria, BC, Canada, 2007, http://www.vtpi.org/traveltime.pdf, Accessed January 2, 2008. Subsequently updated in 2011.

London Assembly Transport Committee 2009, *Too close for comfort Passengers experience of the London Underground,* December 2009.

London Underground Limited 1993, Operations Research Memo.

Maynard, A 2007, *Monetising the Benefits of Disabled Access in Transport Appraisal,* Transed 2007 Conference Transport Canada.

McIntosh, P T & Quarmby, D A 1970, *Generalised Costs and the Estimation of Movement Costs and Benefits in Transport,* Mathematical Advisory Unit Note 179, Department for Transport. Also available in Highway Research Record 383 (1972) pp.11-26.

Mazloumi, E, Currie, G & Sarvi, M 2008, *Assessing Measures of Transit Travel Time Variability Using AVL Data,* Transportation Research Board Meeting Washington DC USA.

Miller, T R 1996, *The Value of Time and the Benefit of Time Saving*, National Public Services Research Institute, May 1996.

Mishalani, G, McCord, M & Wirtz, J 2006, *Passenger wait time perceptions at bus stops: Empirical results s and impact on evaluating real-time bus arrival information,* Ohio State University, Journal of Public Transportation, vol 9 no 2.

NZ Transport Agency 2016, Economic evaluation manual,
https://www.nzta.govt.nz/resources/economic-evaluation-manual

Outwater, M L, Spitz, G, Lobb, J, & Campbell, M 2010, Resource Systems Group TCRP H-37*, Characteristics of Premium Transit Services that Affect Mode Choice Summary of Phase I.*

Pacific Consulting 1995*, Value of Rail Service Quality,* report to State Rail Authority Planning and Development 1996.

PCIE 1996*, M2 Busway Survey Market Research,* report to Department of Transport NSW, some results summarised in Prosser et al. (1997).

PCIE 2000, *Sungold / Citywest, Stated Preference Market Research,* for Ove Arup Pty for QR by PCIE.

PCIE & BNR Consulting 2000, *Sydney to Newcastle Rail Upgrade Project - Patronage Analysis,* for State Rail Operations Development by PCIE in association with BNR Consulting, June 2000.

Piotrowski, S 1993, *Transfer Penalty Research in Perth, Western Australia*, report by Travers Morgan Pty.

PPK-PCIE 1998, *Liverpool to Parramatta Transitway Feasibility Study,* market research working paper, report to the Department of Transport by PPK Environment and Infrastructure Pty Ltd, August 1998.

Prosser, N, Douglas, N J & Jones, M J 1997, *Development of a Patronage Demand Model for the Proposed Parramatta – Chatswood Rail Link"* by Prosser, N, Douglas, N J & Jones, M J, paper presented at the 21st Australasian Transport Research Forum, Adelaide, September 1997.

RPPK & PCIE 1996, *Parramatta-Chatswood Market Research Report,* patronage report to Rail Access Corporation.

SDG 1990*, Critical corridors assessment forecasting the demand effects of bus competition,* report to New Zealand Rail.

SDG 1991*, The effects of quality improvements in public transport,* Part IIB detailed Market Research results and parameter estimates, final report to Wellington Regional Council, April 1991.

SDG & GHD-Transmark 1992, *Estimation of Elasticities for Primary Service Attributes*, report by SDG & GHD-Transmark for CityRail NSW.

SDG 1996*, Bus Passenger Preferences,* report to London Transport Buses.

SDG 2007*, Phase I Willingness to Pay Valuations,* memorandum to Transport for London 23rd July 2007.

Strategic Rail Authority 2002, *Appraisal Guidance*, September.

Transport for London 2004, Business Case Development Manual.

Transport for London 2008, Business Case Development Manual, report issued by TfL Investment Programme Management Office, May 2008.

Transport for London 2013, Business Case Development Manual, London.

TfNSW 2020 'Economic Parameter Values'

https://www.transport.nsw.gov.au/projects/project-delivery-requirements/evaluation-and-assurance/technical-guidance

Travers Morgan 1995, *Market research for demand forecasts for Western CBD extension of Sydney LRT,* Sydney, Australia: NSW Department of Transport.

Trompet, M X, Lui & D J. Graham 2011, *Development of Key Performance Indicator to Compare Regularity of Service Between Urban Bus Operators*, Transportation Research Record: Journal of the Transportation Research Board, No. 2216: pp. 33–41.

Vincent, M 2008, *Measurement Valuation of Public Transport Reliability, (*No. Report 339) for NZTA, Wellington, New Zealand.

UK Government 2017, WebTAG – Transport analysis guidance, https://www.gov.uk/guidance/transport-analysis-guidance-webtag

Wallis I.P. & Gromit N.J. (2013) *"Predicting the Value of Public Transport In-Vehicle Time"* Paper presented at the Australasian Transport Research Forum 2013 Proceedings 2nd - 4th October 2013 QUT Gardens Point Brisbane, Australia. http://atrf.info/papers/2013/2013_douglas_wallis.pdf

Wallis I & Associates 2008, Wellington City Bus Priority Plan – Evaluation Draft 4, report to Wellington City Council. 18 April 2008 by Ian Wallis & Associates Ref: N012/Rep/1056 study.

Wang 2014*, Economic Evaluation of Travel Time Reliability in Road Project Planning: a Practitioner's Perspective*, paper given at the 26th ARRB Conference – Travel Time Reliability, Sydney, New South Wales 2014.

Wardman, M & Whelan, G 2001, 'Valuation of improved railway rolling stock: a review of the literature and new evidence', in *Transport Reviews*, Volume 21, Number 4, 1 October 2001, pp. 415–447(33).

Wardman, M 2001a, *A review of British Evidence on Time and Service Quality Valuations,* Transportation Research Part E 37, pp 107–128.

Wardman, M 2001b*, Inter-temporal Variations in the Value of Time,* ITS working paper 566, ITS Leeds, UK.

Wardman, M 2014, Valuing convenience in public transport: Roundtable summary and conclusions", International Transport Forum Discussion Paper, No. 2014-02, http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201402.pdf

Weston, J G 1989, *Train Service Model - Technical Guide*, London Underground Operational Research Note 89/18.

Appendix

Table 71: List of Australian & NZ studies reviewed

#	Label	Loc	C	Year	Ref	Client	By	Survey	Type	Users	Method	Sample	ASC	Access	Freq	Wait	Disp	IVT	Fare	Transfer	Crowd	Reliab	Veh Qual	Stop Qual	Fare	Car	Description
1	WR90	WTN	N	1990	SDG (1990)	NZ Rail	SDG	SP	RvBvC	Rail	Int	1005	y	y	y			y	y						y		Forecasting the demand effect of bus competition on rail
2	WQ91	WTN	N	1991	SDG (1991)	WRC	SDG	SP	PTvPT	All	Int	335			y				y		y	y	y	y	y		Effects of Quality Improvements in PT
3	ALRT91	AKL	N	1991	SDG (1991)	ARC	SDG	SP	LvB	All	Int	750	y	y	y			y			y		y	y	y		Public Preferences for Auckland LRT & Busway for ARC / No VOT reported
4	SydR92	SYD	A	1992	SDG(1992)	City Rail	SDG/T	SP	RvBvCv W	Rail	Int	1077	y	y	y			y	y	y					y	y	Estimation of Elasticities for Primary Service Attributes for Sydney Rail
5	Per93	PER	A	1993	Piotrowski (1993)	WA DoT	TM	SP	PTvPT	PT	SCQ	1616	y							y							Before and after SP of transfer penalties as part of modelling impact of new service.
6	SL95T	SYD	A	1995	TM (1995)	NSW DoT	TM	SP	B/L v C	B,C,W	Int	nk	y	y	y			y	y	y	y				y	y	Mkt research for Demand forecasts for Western CBD Extension of Sydney LRT
7	SL95B	SYD	A	1995	BAH (1995)	NSW DoT	BAH/PC	SP	PTvPT & Trnsfr	B,R,W	Int	≈500	y	y	y			y	y		y				y		Parameters for Ultimo Pyrmont Light Rail Pax Study 2 SPs (Main Mode & Glebe Trf)
8	SRQ95	SYD	A	1995	PCIE (1995)	City Rail	PCIE	2 SP/PE	RvR	Rail	Int	2780									y	y	y	y	y		2 SP surveys plus Priority evaluator to value rail service quality
9	PC96	SYD	A	1996	PCIE (1996)	NSW DoT	RPPK	SP	PTvPT PTvCar	C,B,R	Int	nk	y	y	y			y	y	y					y	y	Estimate parameters for forecasting patronage for Parramatta-Chatswood rail link
10	M2_96	SYD	A	1996	RPPK (1996)	NSW DoT	RPPK	SP	PTvPT PTvCar	C,B	Int	nk	y	y	y			y	y	y		y			y	y	Estimate parameters for forecasting patronage for M2 Busway
11	STM96	SYD	A	1996	Hague (2001)	NSW TDC	Hague	RP	MMRP	All	HSTS	nk	y	y	y	y		y	y	y					y	y	Sydney Travel Model based on Household Travel Survey. Calibration report
12	LivTW98	SYD	A	1998	PPK (1998)	NSW DoT	PPK	SP/PE	PTvPT PTvCar	C,B,R	Int	1196	y	y	y			y	y	y					y	y	SP+Priority Evaluator to estimate parameters for Liv-Par TWay pax forecasts
13	SBQ99	SYD	A	1999	Hensher (2002)	STA NSW	ITS Syd	SP	Bus	Bus	SCQ	3849		y	y			y	y			y			y		Estimation of model to develop service quality index for bus service
14	SBQ00	SYD	A	2000	Hensher (2003)	STA NSW	ITS Syd	SP	Bus	Bus	SCQ	1478		y	y			y	y		y	y			y		Estimation of model to develop service quality index for bus service

#	Label	Loc	C	Year	Ref	Client	By	Survey	Type	Users	Method	Sample	ASC	Access	Freq	Wait	Disp	IVT	Fare	Transfer	Crowd	Reliab	Veh Qual	Stop Qual	Fare	Car	Description
15	BSG00	BRI	A	2000	PCIE (2000)	Ove Arup	PCIE	SP	PTvPT	C,PT	Int	623	y	y	y			y	y						y		Parameters estimation for demand forecasts for suburban Brisbane rail services.
16	BJ00	SYD	A	2000	Halcrow (2000)	Lend Lease	Halcrow	SP	RvR	C,B,R	Int	1649		y		y		y	y						y		Estimate parameter for patronage forecasts for extending Bondi Junction rail line.
17	SdNw00	SYD	A	2000	PCIE (2000)	SRA	PCIE	SP	RvR	Rail	Int	255			y			y	y	y					y		Parameter estimation for demand forecasts for faster Sydney-Newcastle rail.
18	Bri01	BRI	A	2001	Douglas (2003)	BCC	BAH/PCIE	SP	PTvPT PTvCar	C,B,R,F	Int	≈3000	y	y	y			y	y	y					y	y	Estimate demand forecasting parameters.
19	SFry01	SYD	A	2001	BAH (2001)	Syd Ferry	BAH/PCIE	SP	FvB FvC	B,F	Int	841	y	y	y			y	y	y		y			y		Estimate demand parameters for business model of Sydney ferries.
20	NZEM02	ACW	N	2001	Beca (2002)	Trans fund	SDG	SP	BvB RvR	B,R	SCQ	815			y			y	y	y	y	y			y		2 SPs (VOT & Rel/Crwd) of AUC, CHC & WTN PT users. Values were basis of NZ EEM.
21	Can03	CAN	A	2003	BAH(2003)	ACT	BAH	SP	BvB BvTxi/C	C,B,T	Int	586	y	y		y		y	y						y	y	Estimate parameters for fare elasticities for Canberra bus services.
22	SydR03	SYD	A	2003	Douglas (2003)	SRA	DEL	SP	RvR	Rail	Int	1578			y			y	y	y					y		Estimate primary service parameters for economic appraisal of rail services.
23	SNW03	SYD	A	2003	Hensher (2003)	NSW DoT	ITS Syd	SP	Multi Modal	C,B,R	SQC	453	y	y	y	y		y	y	y					y	y	Estimation of parameters for model to forecast demand for new PT in NW Sydney.
24	SLRT03	SYD	A	2003	BAH (2003)	NSW DoT	BAH/DE	SP	LvB LvBvR	C,B,R	Int	1063	y	y	y	y		y	y	y					y		Parameter estimation for Sydney LRT ext. demand forecasts.
25	SRSC04	SYD	A	2005	Douglas (2005)	Rail Corp	DEL	SP	RvR	Rail	Int	335		y		y					y						Estimation of station crowding values relative to platform waiting.
26	SRQ05	SYD	A	2005	Douglas (2006a)	Rail Corp	DEL	Rating	RvR	Rail	Int	nk						y	y			y	y	y	y		Estimation of service quality via passenger ratings.
27	DND05	MEL	A	2005	Halcrow (2005)	VTIDpt	Halcrow	SP/PE	RvR	Rail	Int	103					y	y	y		y	y	y		y		Rail study. VoT too high (>$30/hr) and omitted.
28	SRTC06	SYD	A	2005	Douglas (2006b)	Rail Corp	DEL	SP	RvR	Rail	Int	584				y		y	y		y						Valuation of Sydney train crowding for economic evaluations.
29	STM06	SYD	A	2006	Fox (2010)	BTS Syd	Rand	RP	MMRP	All	Int	55812	y	y	y	y		y	y						y	y	Sydney Travel Model based on Household Travel Survey.
30	SunV06	MEL	A	2006	BAH (2006)	VDoI	BAH	SP	RvR	Rail	Int	2031			y			y	y		y	y	y	y	y		Survey of suburban and longer distance rail into Melbourne. SP and

#	Label	Loc	C	Year	Ref	Client	By	Survey	Type	Users	Method	Sample	ASC	Access	Freq	Wait	Disp	IVT	Fare	Transfer	Crowd	Reliab	Veh Qual	Stop Qual	Fare	Car	Description
																											priority evaluator for quality attributes.
31	WTLY08	WTN	N	2008	Wallis (2008)	NZ Bus	IWA	SP	BvB	Bus	Int	122						y	y		y						Mkt research on trolley bus seat layout.
32	NZRI08	A&W	N	2007	Vincent (2008)	Trans fund	BAH	SP	RvR BvB	B,R	Cint	751						y	y			y			y		Internet survey of Auc bus & Wel bus and rail users. Surveys undertaken in 2007.
33	AusTC10	CAP	A	2010	CRC (2010)	CRC	CRC	SP	RvR	All	Cint	1800						y	y		y				y		Internet survey of rail & non rail users about train crowding in Adl, Bri, Mel, Syd, Per.
34	SMet11	SYD	A	2011	Hensher (2011)	NSW DoT	ITS Syd	SP	Multi Modal	All	Cint	524	y	y	y			y	y	y	y				y	y	Internet survey of parameters to forecast demand for Metro services in NW Sydney.
35	SRVoT12	SYD	A	2011	DEL(2012)	Rail Corp	DEL	SP	RvR	Rail	Int	1672					y	y	y						y		Valuation of time and displacement for rail economic appraisals.
36	SIC12	SYD	A	2012	Douglas (2013)	BTS Syd	DEL	SP	PTvPT	B,R	Int	939						y	y	y					y		Value of different types of interchange.
37	NZPS13	ACW	N	2013	Douglas (2014)	NZTA	DEL	SP	BvB RvR	B,R	SCQ	5048			y	y		y	y				y	y	y		Value of quality survey of bus & rail users in AUC, CHC & WTN. Large sample of 12,557 incl 5048 SP surveys.
38	InSyd13	SYD	A	2013	DEL (2014)	BTS Syd	DEL	SP	PT v PT	B,L,R	SCQ & Int	4674	y		y	y	y	y	y	y	y		y	y	y		4674 SP + 2036 Rating surveys using self-comp q'aires & interviewers of bus, LRT & rail users in Inner Sydney.
39	MelInfo	MEL	A	2014	DEL/SW (2014)	PTV Mel	DEL/ Sweeney	SP	PT v PT	B,L,R	SCQ	1800			y	y		y	y				y	y	y		Value of quality survey of bus, tram (L) & rail users in MEL. (900 Rating & 900 SP surveys).
40	Syd14	SYD	A	2014	Legaspi (2015)	TfNSW	DEL	SP	PTvPT	B,L,R,F	SCQ				y	y		y	y				y	y			Systemwide survey of rail, bus, LRT and ferry users covering Sydney, Newcastle and Wollongong. Some overlap with study 38.

Table 72: List of 'Vehicle & Stop Quality' studies reviewed

#	Ref	Label	Description	Ref	Client	Location	Year	Modes
1	2	WQ91	*Quality of Public Transport*	*SDG (1990)*	*WRC*	Wellington	1991	Bus & Rail
2	8	SRQ95	*Value of Rail Service Quality*	*PCIE (1995)*	*City Rail*	Sydney	1995	Rail
3	12	LivTW98	*Liverpool-Parramatta Transitway*	*PPK (1998)*	*NSW DoT*	Sydney	1998	Bus
4	13& 14	HenBS	*Developing a Bus Service Quality Index*	*Hensher (2002,03)*	*STA NSW*	Sydney	1999-02	Bus
5	25	SRQ05	*Value of Sydney Rail Service Quality*	*Douglas (2006a)*	*City Rail*	Sydney	2004-5	Rail
6	27	DND05	*Survey of Dandenong Rail Quality*	*Halcrow (2005)*	*VTIDpt*	Victoria	2003	Rail
7	41	UKRS	*Valuing UK Rolling Stock*	*Wardman (2001)*	*UK Rail*	UK	Pre 2001	Rail
8	42	WTNRST	*Wellington Station Quality*	*Doug Econ (2005)*	*Tranz Metro*	Wellington	2002/05	Rail
9	43	SDGLND	*London, Bus & Train Values*	*SDG (1995,07)*	*TfL*	London UK	1995-07	Bus & Rail
10	44	LDSSQ	*Bus Quality Package Values*	*Evmorf-opoulos (2007)*	*MSc Dissertation*	Leeds UK	2007	Bus
11	45	AECOMBS	*Soft Measures influencing Bus Patronage*	*AECOM (2009)*	*UK DoT*	UK Cities	2009	Bus
12	46	USPT	*Valuing Premium Public Transport*	*Outwater (2010)*	*US FTA*	4 US Cities	2010	Bus & Rail
13	47	NORPT	*Universal Design Measures in PT*	*Hammer (2007)*	*Public Roads Admin*	Norway	2007	Bus

INFRASTRUCTURE AND TRANSPORT MINISTERS